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Earthworms of the Western United States
Part 1. Lumbricidae

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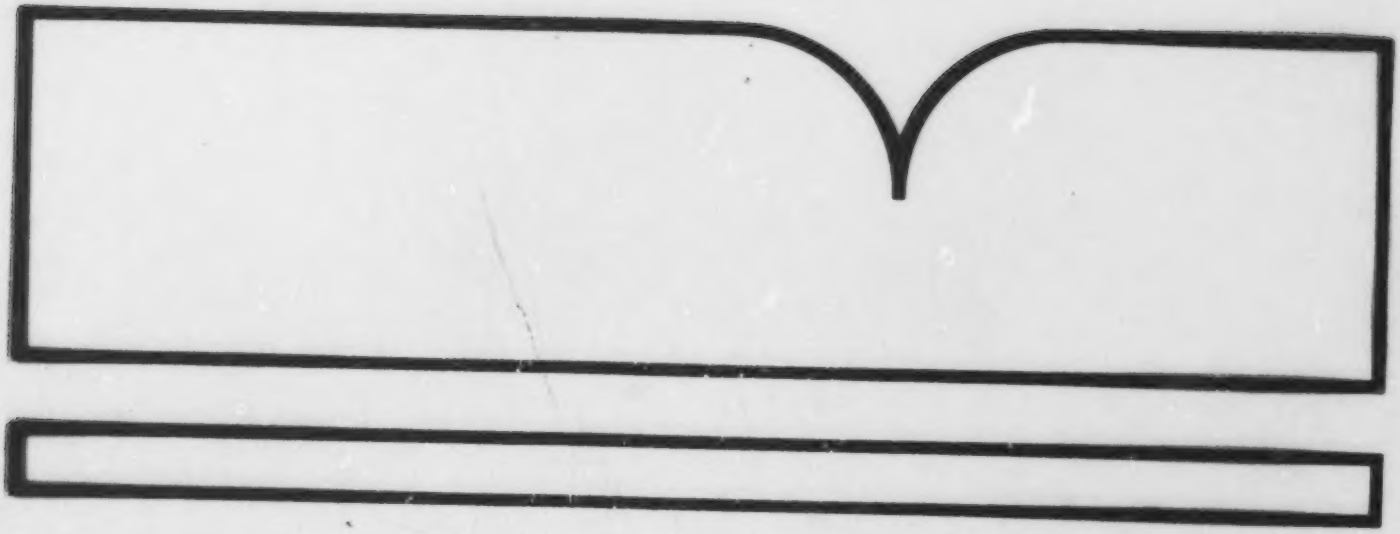

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The earthworm fauna of the western United States is an amalgam of native and introduced elements. While the native species are mostly members of the family Megascolecidae, and closely related to those of Australia and Southeast Asia, the introduced species are, at least in the North, members of the family Lumbricidae, and mostly native to Europe, though some, Bimastos parvus and B. tumidus, have come from eastern North America.

This present work stems from a need, identified by the U.S. Environmental Protection Agency, to determine the potential toxicity of various hazardous wastes to soil organisms. Earthworms, because they burrow through and ingest the soil, are a determining factor in the aeration, drainage, and fertility of moist soils, making them an important ecological component of the soil system. In many respects, they are a link between the soil microbial and higher plant communities. Further, they are an important and often necessary food source for many other organisms, both vertebrates and invertebrates. Adverse effects on local earthworm populations might therefore indicate a potential for a far more general adverse impact. In consideration of these factors, the Environmental Protection Agency has incorporated an Earthworm Viability Assessment into a protocol for assessing the biological effects of hazardous wastes.

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EARTHWORMS OF THE WESTERN UNITED STATES. PART I. LUMBRICIDAE

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INTRODUCTION

The earthworm fauna of the western United States is an amalgam of native and introduced elements. While the native species are mostly members of the family Megascolecidae, and closely related to those of Australia and Southeast Asia, the introduced species are, at least in the North, members of the family Lumbricidae, and mostly native to Europe, though some, *Bimastos parvus* and *B. tumidus*, have come from eastern North America.

The study of "wild" earthworms in the West has mostly been confined to taxonomic study of the native taxa. Benham (1892), Eisen (1893, 1894, 1895-6, 1900), Smith (1897, 1937), Altman (1936), and Michaelsen (1921) all contributed species descriptions of western earthworms, and in some instances provided minimal ecological data. Eisen and Altman, especially, tried to relate their species to habitat. They were, in fact, the only two of the above researchers who actually lived in the West and saw these worms in their native haunts. James A. Macnab and Dorothy McKey-Fender, in 1944, took up the study of western earthworms and continued the work of classifying the native fauna. During this time, the work was supported by an intensive collecting effort, including detailed collection notes on associated trees, habitat type, soil pH, *etc.* Again, the main effort of these researchers was with the native Megas-

colecidae and resulted in a series of new descriptions (1946-1960), but many of their collections included introduced Lumbricidae which were becoming increasingly common in disturbed areas and could not be ignored. While these interlopers were duly identified and recorded, most of the specimens were sent to G. E. Gates, who was then revising the adventive lumbricid species. Many of these records have been entered into the literature in Dr. Gates' numerous publications. After discontinuing her partnership with Dr. Macnab, Mrs. McKey-Fender worked alone, primarily on a generic revision of the native taxa (contrary to published reports that her research had been terminated) and then in 1974 was joined by this author (her son), who has continued to do intensive collecting and revisionary work.

One of the most important of Dr. Gates' works with reference to western Lumbricidae was his "Great American Desert" paper (Gates, 1967) which was based largely on the collections of Prof. D E. Beck in the intermontane west. It is this work which has provided most of the locality records for earthworms in the rain shadow east of the Cascade Range and the Sierra Nevada and west of the Great Plains. It is interesting to note that this work did not report a single native species from the area of study.

The combination of lumbricid species encountered in the West has not been treated by any single work and no key is available which can deal with all of them, so the keys in this work have been created *de novo*, without reference to any other. They were revised several times in an attempt to make them more usable and several taxa were included which have not yet been reported in the West but which are peregrine and are considered likely to turn up eventually.

In the event that unidentifiable species are encountered, one should consult references by Gates (1972a), Graff (1953), Gerard (1964), and Bouché (1972), which together should cover any presently described species of lumbricid likely to be encountered in the West.

This present work stems from a need, identified by the U.S. Environmental Protection Agency, to determine the potential toxicity of various hazardous wastes to soil organisms. Earthworms, because they burrow through and ingest the soil, are a determining factor in the aeration, drainage, and fertility of moist soils, making them an important ecological component of the soil system. In many respects, they are a link between the soil microbial and higher plant communities. Further, they are an important and often necessary food source for many other organisms, both vertebrates and invertebrates. Adverse effects on local earthworm populations might therefore indicate a potential for a far more general adverse impact. In consideration of these factors, the Environmental Protection Agency has incorporated an Earthworm Viability Assessment into a protocol for assessing the biological effects of hazardous wastes (Porcella, 1983). Because this procedure requires a basic knowledge of local earthworm ecology, the present work was undertaken to help ientify specimens, locality, and habitat type for western earthworm species, especially Lumbricidae which are the most probable species to be encountered in areas polluted by hazardous wastes.

While none of the species reported in this volume is new, much of the locality and habitat information is unpublished, or has been abstracted from other works to be more usable to this purpose. The sources of the information are various, but include collection records in the McKey-Fender collection, an unpublished M.A. thesis (Macnab, 1931), the various cited references by Gates, Altman (1936), Smith (1917), Gerard (1964) on British earthworms, Edwards and Lofty (1972) on the biology of earthworms, and Bouché (1972) on earthworms of France. Finally, much of the habitat information is based on personal collecting experiences of Dorothy McKey-Fender and myself.

The descriptions contained in this work are partially original and partially derived from the literature. The variations in length, segment number, tubercula pubertatis, clitellum, and dorsal pore position are usually derived from various works by Gates, and from Gerard (1964). Description of the internal features and some external features are drawn from personal observations by this author, and have been checked against published descriptions. While features of earthworm anatomy will vary somewhat, this variation is usually within fairly narrow limits around a mean. Certain individuals, however, may be highly aberrant. *Aporrectodea trapezoides*, for example, usually has a tuberculum pubertatis on 31-33, but may have this structure extending onto 30 and/or 34 as well. Extreme variability of sexual structures is a common feature of parthogenetic populations. This problem can be countered by using both keys to species in difficult cases.

The descriptions are not complete, and include only those features which this author feels to be of some use in determining the taxa involved. For further descriptive material, see Gerard (1964), Bouché (1972), and most especially the various cited references by Gates.

METHODS

I. COLLECTION

Collection of earthworms is accomplished by several different methods, each of which has its advantages and drawbacks. These methods are summarized and referenced in such works as Reynolds (1977a), Edwards and Lofty (1972), Gerard (1964), Bouché (1972), *etc.* The following list is not exhaustive but should give an introduction to the commoner methods.

Digging and Handsorting

This is the method we have used almost exclusively and with great success. Its drawbacks are that it is hard work, that it skews collections to larger specimens, the smallest ones often being lost, that it is very difficult in soil with many woody roots or with many stones, and that it results in many damaged specimens. Despite this, it is an excellent means of obtaining all of the species present at a particular site. For general survey work, one should examine all microsites including trails, open areas, under individual shrubs or trees, *in and under* forest litter, by banks of streams, under logs and stones, and in clumps of grasses, rushes, or other fibrous rooted plants. Each of these habitats may contain different species. For quantitative work, arrays of known surface area can be sampled by this method as well as the others.

Washing

This basically involves rinsing a substrate (known volumes for quantitative work) through a fine-meshed screen. This is as labour-intensive as digging and handsorting and is useful mainly where samples are brought to a laboratory, where large volumes of water are available, or for collecting mud-inhabiting species adjacent to lakes or streams. In this last habitat, mud coating the worms can make them invisible unless they are washed. This is a good method for obtaining all specimens in a given volume, including cocoons and estivating worms.

Chemical Expulsion Method

We have rarely used this method. In it, a dam is set up around a specified area of soil surface and a dilute solution of some irritating chemical poured onto the soil surface. Many species will react to this by coming out onto the surface to escape the irritant. Unfortunately, this does not work equally well with all species, being most suited for species which live near the surface or in permanent burrows. It will not work for estivating specimens, and deep burrowers will sometimes retreat to lower levels. With some species, for instance *L. terrestris*, it is a good quantitative method. This method can be less labour-intensive than digging and handsorting, except in off-road areas to which large quantities of fluid must be transported on one's back!

Solutions found useful include formaldehyde (*ca.* 0.5%), potassium permanganate (*ca.* 0.15%), and mercuric chloride (*ca.* 0.1%) (Edwards and Lofty, 1972).

Electric Expulsion Method

This is accomplished through the use of electrodes attached to an electrical source and driven into the soil. We have never used this method. Advantages and drawbacks are similar to those of the chemical method, with the added problems that worms very near the electrodes may be killed, that it is difficult to know what volume is being sampled, that the effectiveness of the method will depend on the moisture content of the soil, and that the method requires access to a source of electricity.

Mechanical Vibration

Numerous variations on this method are used, including pounding a post into the ground, stamping with one's feet, scratching the soil surface, *etc.* This may mimic the vibrations produced by moles, the earthworms coming to the surface to escape the predator. Reynolds (1977a) writes that this method is unheard of in Europe and that it does not work with the Lumbricidae, only *Diplocardia*, in the United States. I have used this method to collect various Lumbricidae in Oregon, including *Lumbricus castaneus* and others. It has, however, only proven useful in very moist conditions when the worms are at maximum activity.

This method, like the chemical and electrical methods, is species-specific and not a good method for general collection.

Edwards and Lofty (1972), who review the methods in some detail, conclude, "There seems little doubt that hand sorting or washing gives the best results for most species but are very time consuming. At present, the formalin method seems the best compromise for species with burrows."

On Collecting Microsites

While it is tempting to collect worms by jumping out of the car and turning over logs, stones, or junk adjacent to a highway, this is the worst possible approach, at least in the West. Roadside earthworms are almost always limited to those which inhabit disturbed areas and which are resistant to roadside chemicals, *i.e.*, car exhausts, heavy metals, petroleum residue, *etc.* As well, only a few species are likely to be found under stones. All of these factors badly bias roadside collection. For a fairer assessment of earthworm populations, it is necessary to go at least 20 meters away from roadways before collecting.

Another important fact is that many species preferentially inhabit game trails and other compacted soils, or the mosses on top of logs, and these sites should not be overlooked. Do not fall into a pattern of collecting only the easiest habitats.

Collection Records

For taxonomic or ecological usefulness, collections must be accompanied by certain data, including *at least* date, location, collector, and habitat. Important habitat records are dominant vegetation, at least the trees and shrubs, site type (*e.g.*, river bank, bog, game trail), soil type, and pH. Elevation can usually be obtained from maps afterwards, as can Township, Range, and Section. Locations should be specified well enough to allow re-collection of the same site, within one kilometer if possible. For collection number, we simply append a number to the date, sometimes adding a letter for different habitats at the same locality. A sample data sheet (Figure 1) follows, but I recommend that each researcher modify it as it suits his or her needs.

II. LIVE STORAGE

Most earthworms can be stored in the medium in which they were collected for at least one, sometimes several, months. Plastic

Date_____ Collection no._____

Collectors_____

Locality_____

_____

Elevation_____ Site_____

Dominant Vegetation_____

_____

_____

Soil (texture, color, pH)_____

_____

Other (Appearance, Activity, Odor, Assoc. spp.):

Figure 1. Sample data sheet for collection records.

(polyethylene) bags are convenient because they allow diffusion of oxygen, yet prevent the escape of both water and worms. An external label is essential, however, because earthworms will eat paper.

Earthworms to be stored should be examined for injury and damaged worms discarded or preserved.

Temperature is a critical factor for earthworm survival. For most worms collected outdoors in cool-temperate areas, refrigerator storage (1°-10°C) gives good survival. For worms collected in warm-temperate to subtropical areas or heated greenhouses, an incubator set to 15-20°C (not less than 10°C) is more appropriate. Most earthworm species should be able to tolerate a 15°C incubator. For most species likely to be collected in the western United States, excess heat is a greater danger than excessive cold (see notes under Transport).

Some species are very sensitive to pH. For this reason, it is critical to avoid altering this factor for newly collected specimens. Worms should remain in their natural medium until this can be tested, and care should be taken to ensure that this truly was the medium in which they were living. Testing this pH should be done quickly, because earthworms will alter the pH (usually upward) of the medium in which they are living. Interestingly, the moisture content of the medium is less critical than most factors at first, as long as there is *enough* moisture. Earthworms rarely drown, although they will dessicate.

III. TRANSPORT

Live earthworms may be transported in their original medium in most instances, provided a few precautions are taken.

Temperature is of utmost importance. The worms must be protected from both high and low temperature extremes, and the best way to accomplish this is to enclose them in an insulating container, or alternately to put them in a large volume of soil or other thermal mass. For field collecting during the summer, a "cooler" with ice is indispensable.

Earthworms require little oxygen, but will suffocate if in an absolutely airtight container for sufficient time. Polyethylene plastic bags are permeable to oxygen and worms can be kept in them for many months.

Some clay soils will compact (puddle) when subjected to vibration. This has not proven too much trouble when transporting specimens by car back to the laboratory from the field, but might be troublesome in shipping worms across country. It may be ad-

visable in such cases to transfer the worms to a looser medium, such as moist paper towelling. Precautions about pH stated in the Storage section apply here.

IV. PRESERVATION

Proper fixation and preservation of earthworms is essential for taxonomic study and, in many cases, simple identification. The following procedure is based on techniques developed over the last fifty years by James A. Macnab, Dorothy McKey-Fender, and this author. It is partly derived from a standard method developed for use with marine invertebrates.

What is loosely called "preservation" in general usage is at least three separate steps, killing, fixing, and preservation, each of which has a distinct function. For earthworms, a fourth step, anesthetization, is necessary to obtain well-extended, and therefore easily dissectible, specimens. Failure to recognize this fact often results in specimens being dropped into a small vial of alcohol where they slowly decay, eventually becoming useless.

The following solutions are necessary for optimal preservation of earthworms (see recipes following this section):

1. Saturated $MgSO_4$ (Epsom salts) in water
2. Bouin's fixative
3. Lavdowksy's fluid (FAA)
4. 4% formaldehyde (9 parts water: 1 part commercial formalin)

Anesthetization

Place the worms in a solution containing 1 part saturated $MgSO_4$ solution (epsom salts) to 4 parts water and leave them until they no longer respond to a mechanical stimulus. This should take one to two hours. For resistant species, additional $MgSO_4$ solution may be added a little at a time.

Alternatively, put the worms in water and then add ethanol slowly, drop by drop, until they are anesthetized, and then transfer them to FAA (step 3). This is a tricky technique since too much ethanol will cause the worms to shorten irreversibly, but is more rapid than $MgSO_4$, especially with the larger species.

Killing

This is best done by dipping the worms briefly (1 to 2 seconds for smaller worms, up to 20 seconds for the larger) in Bouin's picro-formol. They should be placed straight, but not stretched, on a flat surface for about one minute. A sheet of paper is best to absorb excess Bouin's. If Bouin's is not available, this step may be omitted, but at the risk of irreversibly shortening the worms in the next step.

Fixation

Place the worms in a long V-shaped container filled with Lavdowsky's fluid (FAA); a dissecting pan elevated on one side works nicely. This helps to keep the specimen straight, which is of tremendous value when they are being dissected. When the worms have stiffened, put them in a glass tube or other suitable container with fresh FAA.

Preservation

After several hours, overnight will do, replace the FAA with either 4% formaldehyde or 70% ethanol. Formaldehyde must not be allowed to touch cork (such as a cork stopper) or the specimens will be blackened beyond use, so tubes must be kept upright if this system is used. In any case, the preserving fluid should be replaced in 24-48 hours, since the earthworm's body fluids will dilute it significantly. This is extremely important with large collections, and is the commonest mistake made by beginning earthworm collectors.

Variations

We have found that when preserving large numbers of collections for transport or indefinite storage before they are examined, it is convenient to, in step 2, lay the worms, folded if they are large, on 3 x 5 index cards and then to slip the card, worms and all, into a small zip-loc storage bag®[1]. The FAA is then carefully poured into the bag which is then closed. The bag is then hung by the top until fixation is complete. The FAA is then carefully poured out and replaced with 4% formaldehyde. A large number of such bags can be rolled up and placed on end in a 2-liter glass-top French-style canning jar or similar container. When the jar has been filled with samples, it is filled the rest of the way with 4% formaldehyde and can be stored or shipped this way. Locality labels can be written in pencil or India ink directly on the 3 x 5 cards. Ethanol solutions are not suitable for use with polyethylene bags because ethanol will cause the plastic to degrade. The major drawback to this system is that the bags must be removed from the jar while one is using adequate hand protection and ventilation, preferably with running water and/or in a hood. The major advantages are that it provides for very compact shipping and storage, and restricts the release of and one's exposure to toxic fumes during the preservation process. This is especially advantageous when laboratory facilities are not available, such as when one is on an extended collecting trip.

If necessary, earthworms can be dropped into FAA with no other preparation provided that the initial fixative is CHANGED WITHIN 36 HOURS (see note above under Preservation).

Ethanol is not a fixative for earthworms when used alone and should not be used as such except as a last resort, although it will work as a preservative.

RECIPES

BOUIN'S PICRO-FORMOL

Picric Acid,[2] saturated aqueous solution	75 parts
Commercial Formalin[3]	25 parts
Acetic Acid, glacial	5 parts

LAVDOWKSY'S FLUID (FAA)[4]

Formalin[3]	10 parts
95% Ethanol	50 parts
Acetic Acid, glacial	1 part
Water	40 parts

[1]Use of a trade name is not meant to imply endorsement of a particular company's product rather than another, similar product which may be used instead.

[2]Picric acid is explosive when completely dry, but is safe when stored as a saturated solution. It is not necessary that all of the solid dissolve, as long as it is *wet*. Another good precaution is to immerse the cap of the container in water before opening it. Picric acid is sold as a powder with 10% added water, which is safe, but this cannot dependably be used for long-term storage. Always cover the picric acid with water and use the solution. Check the stock solution regularly and if it accidentally becomes dried, treat it as a high explosive until it can be rewetted.

[3]Formaldehyde is a volatile gas that can easily permeate the atmosphere of a laboratory. Sensitized people can suffer from severe reactions including dermatitis, headaches, dizziness, and respiratory problems, and formaldehyde (along with many other irritants) has been implicated as a carcinogen. Caution is in order, therefore, in any use of formaldehyde, and adequate ventilation is essential. Also, exposure levels which may be of no concern to one researcher may be debilitating to his/her coworkers. Even so, it is the best chemical known for this work, and has no reasonable substitutes, especially for fixation.

[4]Modified.

V. IDENTIFICATION PROCEDURE

To identify earthworms, one will need the following materials:

- Razor Blades—Extremely sharp blades of some kind are essential, and we have been most satisfied with double-edged razor blades. There is obviously some danger in their use, but with reasonable caution this can be minimized. Extremely fine microdissecting scissors or blades may be used instead but are much more expensive. This writer has not cut himself in over 8 years of dissections using double-edged blades. Expect to use a new blade with every second worm, more or less.
- Dissecting Pans—I use small (11 cm x 15 cm x 1.5 cm) pans made of folded sheet metal (1.0 mm thick) with a layer of beeswax on the bottom. Larger pans are usually difficult to maneuver on a microscope stage. Certain flat tins for smoked or canned fish are reasonable and inexpensive.
- Binocular Dissecting Microscope and Light—Identification can often be made using only a hand lens and external characters, but use of a good dissecting microscope is more reliable and is essential when internal characters must be observed.
- Insect Pins—For spreading the body wall during dissection. Most dissections can be done with size no. 2 pins, but small worms will require 0 or 000 pins. Obtain high quality japanned black or stainless steel pins, about 200 of each size.
- Fine Forceps—Straight, fine-point, stainless steel jewelers' forceps are essential.
- Medicine Dropper (preferably with curved tip)—For washing dirt and coelomic corpuscles out of the worm during dissection.
- Water

Place the worm in the dissecting pan and add sufficient water to cover (even several hours in water will not harm specimens preserved by the above methods). At low to moderate power, examine the various external features, writing them down on a 3 x 5 card or other suitable paper.

Note any colour present, and if it is missing in certain areas. Note the shape of the prostomium: is it epolobic or tanylobic? Check the setal spacing. This may be difficult if most setae are not extruded. What segments are covered by the clitellum? Tubercula pubertatis? Genital tumescences? Are the male pores on 15, 13, or 12? Are they prominent? Can spermathecal pores be found? Are they near the dorsal pores at lines *C* or *D*? How many are there?

If the above questions can be answered satisfactorily, then the easiest approach is to use the External Key. This includes all lumbricid species known from North America west of the Rocky Mountains.

For difficult specimens with aberrant or absent sexual features, or which do not seem to fit any species in the External Key, it is best to use the Somatic Key. Several taxa are included in this key which have not yet been found in the West, but which have been found in other parts of North America. Also, this key will show relationships as well as identity.

To use the Somatic Key, it is necessary to dissect the specimen. The following procedure is effective in obtaining the most information for the least work or damage to the specimen.

Before dissecting, note the external information required above. This is to avoid having to take out pins part way through the dissection. The following procedure is based on a right-handed dissection.

Lay the worm out straight and place a pin into and through the floor of the mouth and into the wax to keep the worm with its dorsal surface uppermost. Starting well behind the clitellar region, slice longitudinally, just through the body wall, a little to one side of the dorsal pores. Then pin out the body wall starting from the posterior end of the incision and proceeding anteriorily, alternating sides. It may be necessary to carefully cut the septa to each side of the oesophagus before the body wall can be flattened. Be careful not to use oversize pins if possible so that the body wall is not ripped badly. Some researchers will place pins in every fifth segment to aid in counting, but this becomes less of an advantage with experience as to where structures *should* be.

At this point, features of the nephridia, muscularization, external gut morphology, and sexual system may be determined most easily, whereas once the gut is opened, parts of these structures may be obscured.

Note the number of pairs of seminal vesicles, their segmental location and their position on the septa, and the same with the spermathecae.

The shape and opening of the nephridial vesicle may be obvious *in situ*, but if not, an entire nephridium of one segment should be removed from the immediate post-clitellar region, taking care to get the structures in setal line B, and placed in a drop of glycerine on a slide. It may be useful to stain the nephridium in Staining Solution A (see below) before putting it in glycerine. Be careful to preserve the antero-posterior and dorso-ventral orientation of the nephridium with respect to the earthworm, at least mentally.

The calciferous gland is in the region of x-xiv. Is part of the gland expanded? Which segments? A calciferous sac may be present in segment x (occasionally xi). This appears as a lobe or finger which is often difficult to see beneath vessels, the seminal vesicles, and the septa. Note the shape of the sac, where it joins the oesophagus, and its relationship to any vessels.

Note also the position of the last hearts, taking care not to confuse them with the suboesophageal vessels which join the dorsal vessel in xii, or sometimes x. Usually the last hearts are in xi, but may be more anterior.

Is the gizzard confined to segment xvii or not? Are some septa missing in the gizzard segments?

Once these features have been recorded, the gut should be opened. Similarly to the previous cut, this should start near the posterior end of the opened portion of the worm, and be slightly lateral to the dorsal vessel to avoid cutting the typhlosole in the intestine.

The typhosole should be carefully observed and any grooves, ridges, or pits on its surface should be recorded. The anterior twenty segments or so are the most useful taxonomically. Some information is to be had in the number of atyphlosolate segments in the rectal region, but that character is not used in this work.

The calciferous region (x-xiv) should be examined to confirm the nature and/or presence of a calciferous sac, the location and shape of its opening into the intestine, the position of the openings of the calciferous tubules, and the development of the calciferous tissue (height of the lamellae).

Reference Points

Since segment number of certain internal features is of vital importance, and it is often difficult to count from segment i, certain reference points can be used to assist.

1. The most posterior seminal vesicles *begin* in segment xii.

2. The ovaries are in segment xiii. This is so constant that if the ovaries appear to be in a different segment, one should suspect anterior amputation and regeneration.

3. The second segment contains the first setae.

Staining

The following method as applied to earthworms was described by Macnab and McKey-Fender (1946). Two solutions are required:

Solution A	
Picric Acid[5] (sat. aq.)	50 ml
Indigo Carmine (sat. aq.)	50 ml

Solution B	
Picric Acid (sat. aq.)	50 ml
Acid Fuchsin (sat. aq.)	50 ml

To use this method, the earthworm is dissected dorsally and spread out as described above. It is then stained 20-30 seconds in Solution A, rinsed with water, then stained 10-15 seconds in Solution B. This is a differential stain and greatly increases contrast, especially in fresh material. The stain slowly dissipates and penetrates very poorly, so restaining is necessary after further dissection and after a long time. This stain also helps differentiate external structures such as nephropores.

TAXONOMIC SECTION

I. GLOSSARY

ATRIAL GLANDS: These glands are associated with the male porophore and may protrude into the coelom in segment xv (or xiii). The presence of an intracoelomic component of these glands can be of specific importance.

BODY SHAPE: While most lumbricid earthworms are circular or flattened in x-section (Figure 2a, e), a few are tetragonal (Figure 2d) with setal pairs at the corners. This is especially a feature of aquatic earthworm species.

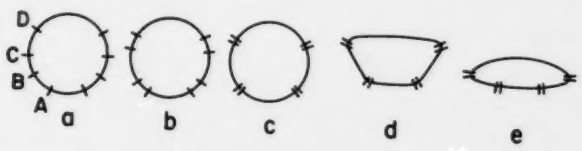

Figure 2. Setal arrangement and body cross-section: **a** to **c**—round cross-section, **d**—tetragonal, **e**—flattened; **a**—setae separate, **b**—setae widely paired, **c** to **e**—setae narrowly paired.

CALCIFEROUS GLAND: Also known as the Glandes de Morren, this is a portion of the oesophagus which produces solid $CaCO_3$ as tiny spherules which are released into the gut. The function of this gland is still in some dispute (Robertson, 1936; Laverack, 1963; Piearce, 1972; Stephenson, 1930). It may in some instances act in pH regulation, either of the blood or intestinal contents. In others it may simply be a means of disposing of excess Ca++, though evidence for this is entirely drawn from experiments on *Lumbricus terrestris*, an ecologically unusual species (Robertson, 1936). In the Lumbricidae, the calciferous gland is composed of numerous parallel longitudinal tubules which are blind at the posterior end. These are located in the wall of the oesophagus in some portion of segments x-xiv. These tubules are formed by the fusion of the ental edges of longitudinal lamellae produced from the inner wall of the pores at their anterior ends (Smith, 1924). When calciferous sacs (q.v.) are present, these spherules are retained in the sacs and, at least in *L. terrestris*, are cemented into large concretions which are relatively insoluble (Robertson, *loc. cit.*). In cases where the calciferous sacs are lacking, such as *Eisenia* spp., the spherules are dumped directly into the oesophagus where they mix with incoming food.

Taxonomically useful characters of lumbricid calciferous glands include presence or absence of calciferous sacs, their morphology, relative size of gland segments and septal construction of the gland, and position of the tubule openings.

CALCIFEROUS SACS: These are paired evaginations (pouches) of the oesophagus wall in segment x or xi (always x in our species) which contain anterior extensions of the calciferous lamellae and the pores of the calciferous tubules. These structures are taxonomically useful in their presence or absence, whether they open in mid-segment or at the posterior margin of the segment, and whether they are produced as digitiform lobes or as vertically oriented reniform pouches opening on their inner sides by vertical slits.

CLITELLUM: This is the "ring" of white, pink, orange, or otherwise colored fleshy glandular tissue which is the most visible feature of a mature earthworm (Figure 3). It is this tissue which secretes the cocoon into which the egg and sperm are released. The cocoon is a nutrient-filled leathery case which is the incubator for the embryonic worm. The usual lumbricid clitellum is saddle-shaped, incomplete ventrally, and its segmental position is of taxonomic usefulness. Full extent of the clitellum varies somewhat, but only within rather narrow limits for each species.

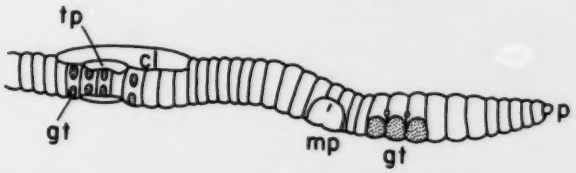

Figure 3. Ventrolateral view of *Apporectodea trapezoides* showing prominent external features: **cl**—clitellum, **tp**—tubercula pubertatis, **gt**—genital tumescences, **mp**—male porophore, **p**—prostomium.

DORSAL PORES: In the mid-dorsal line of most earthworms is a row of pores in the intersegmental furrows. These communicate directly with the coelom and may release coelomic fluid when the worm is irritated or excessively dry. In some worms, the coelomic fluid may spurt several inches. The position of the anterior-most dorsal pore may be quite invariable for some lumbricid species, but since it is extremely variable for others (Fender, 1982), it is not used in this key.

FEMALE PORES: Also called ovipores, these are always on segment 14 in the Lumbricidae, and are either median to seta *a* (*Eiseniella*) or lateral to *b* (all others).

GENITAL TUMESCENCES: These are glandular pads associated with particular setae or setal pairs. They are usually on *ab* but may be on *cd* anteriorly in some species (Figure 3).

GIZZARD: A mixing, and to some extent triturating, organ found in the Lumbricidae in the intestine in the area of segments xvii-xx. In most species it appears to be derived from xvii, though in some species it is more posterior.

[5]See earlier cautions on use of picric acid (page 96).

HEARTS: The anterior connecting vessels between the dorsal and ventral vessels (Figure 4). These pulse in life, and help to create positive pressure in the ventral vessel, which then supplies the capillaries of the entire body. They are present in most lumbricidae in segments vii-xi, but are sometimes lacking in xi and x. A large vessel connecting to the dorsal vessel will often turn out to be the extra-oesophageal (Figure 4). This is a negative-pressure vessel which returns blood to the dorsal vessel, often in segment xii though in other segments in some taxa. For a detailed study of the circulation in *Lumbricus terrestris*, see Bell (1947, 1957).

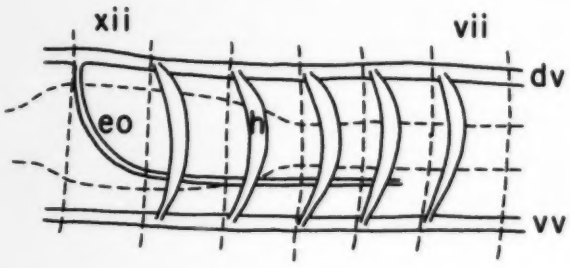

Figure 4. Vascular system, segments vii-xii of *Aporrectodea trapezoides;* **dv**—dorsal vessel, **vv**—ventral vessel, **eo**—extraoesophageal vessel. Septa and oesophagus are outlines with dashes.

MALE PORES: These are in BC, usually on segment xv, and are usually associated with conspicuous glandular porophores. These porophores usually each bear a transverse cleft, the atrium, which secretes a spermatophore of uncertain function. The size, shape, and position of the porophore is of specific importance (Figure 3).

mD; mid-dorsal line.

MALE POROPHORE: The male pores of most earthworm species are associated with external glandular tumescenes. In the lumbricadae these are usually midlateral (in *BC*) pads with a deep cleft, at the bottom of which is the male pore. In some lumbricidae this pad is rudimentary (*Lumbricus castaneus*) or nearly absent (*L. rubellus*).

NEPHRIDIAL VESICLE: The "bladder" of the lumbricid earthworm is an expanded portion of the nephridial duct, just ental to where it enters the body wall. The various shapes the vesicles may assume are figured below, and are described as follows (Figure 5):

The sausage-shaped vesicle is relative short and fat, entering the wall through a terminal duct (Figure 5a).

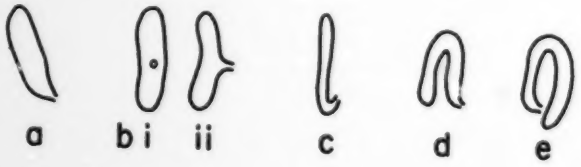

Figure 5. Nephridial vesicle types: **a**—sausage-shaped, **b**—ocarina-shaped, **bi**—median view, **bii**—frontal view, **c**—*Dendrobaena attemsi* type, **d**—U-shaped, ental limb posterior, **e**—U-shaped, ental limb anterior.

Ocarina-shaped (Figure 5b) vesicles enter the body wall through a rather funnel-shaped opening from the ectal *side* of the vesicle, not its terminus. In our species, this vesicle type is associated with a straight series of obvious nephropores (*Dendrobaena octaedra* and *Octolasion* spp.).

The U-shaped or hairpin-shaped vesicle has a 180° bend at the dorsal apex, and its limbs point ventrad, one limb usually being longer than the other. The vesicle enters the body wall through a terminal duct from one limb (Figure 5d, e).

Dendrobaena attemsi has a vesicle which is best termed J-shaped, but its 180° bend is at the ventral extremity. This vesicle terminates at the body wall (Figure 5c), opening either directly to the exterior or into a sub-epidermal duct which passes upward, opening at a higher level.

The nephridial vesicles should be examined behind the clitellum for the typical conformations.

NEPHRIDIUM (pl. nephridia): The "kidneys" of the earthworm, these are looped, glandular tubules on the ventrolateral wall of each somite. They are open to the coelom of the preceding segment by a ciliated funnel and to the exterior by a nephropore (*q.v.*). The main body of ducts is physiologically interesting (see Laverack, 1963), but in the Lumbricidae the main taxonomic usefulness is in the nephridial vesicle (*q.v.*), which is a widened portion of the duct, just ental to its juncture with the body wall.

NEPHROPORE: The exterior opening of the nephridium (found at the anterior margin of each segment starting with segment iii) is variable in dorso-ventral position and visibility. In a few species (*Dendrobaena octaedra* and *Octolasion* spp.), the pores are very obvious and in a straight line above setal line *B* (see SETAE), but in all others the pores alternate between this level and one or more levels higher on the body wall, usually above setal line *D*. In *Dendrobaena attemsi* this alternation is quite regular, but in most taxa it is essentially random, and the pores in the latter case may be quite difficult to detect, as in *Eisenia* spp. It can be safely assumed that in well preserved western Lumbricidae, if nephropores are not detectable, they alternate between two levels, but the reverse is not true.

PROSTOMIUM: A dorsal lobe of the first segment, projecting anteriorly and over the mouth. The prostomium is taxonomically useful in the way it attaches to segment i. The prostomium (Figure 6) is: (a) zygolobic if there are no furrows dividing it from segment i; (b) prolobic if a cross groove is present at the anterior edge of i; (c, d) epilobic if furrows extend longitudinally from the edge of the prostomium over part of segment i; (e) tanylobic if these furrows extend to intersegmental furrow 1/2.

Figure 6. Prostomium types: **a**—zygolobic, **b**—prolobic, **c**—epilobic open, **d**—epilogic closed, **e**—tanylobic. All views are dorsal and show only the prostomium and first segment.

SEGMENTAL LOCATIONS: By convention, each body segment is labeled with a lower-case roman numeral. The prostomium is not considered to be a segment, but the peristomial ring is considered to be segment i (see Figures 3 and 6). The first true metamere is segment ii, which bears the anterior-most setae. Septa and intersegmental furrows are designated by arabic numerals for the adjoining segments, separated by a slash. Septum 11/12 is therefore the septum between segments xi and xii, which are the tenth

and eleventh setigerous segments, respectively. Internal and external segments often do not precisely coincide, so the intersegmental furrow may be slightly anterior or posterior to the corresponding septum. In this work, external segmental locations are given arabic numerals; internal locations are given roman numerals. Use of parentheses, as in "clitellum (20)22-29(30)" *(Bimastos tumidus)*, means that the structure nearly always covers the segments not in parentheses, but that the known extremes are the segments in parentheses.

SEMINAL VESICLES: These are the most conspicuous structures visible internally in the sexual segments of a mature earthworm. They are paired pouches (usually complexly lobed and frothy in appearance) of the septa in which sperm is matured after being released by the testes and before passing into the male funnels. Seminal vesicles are present on the posterior side of septa 10/11 and 11/12 in all species, and are often also, depending on the species, on the anterior side of septa 9/10 and 10/11 as well. When 3 pair of seminal vesicles are present, they are usually anteseptal on 9/10 and postseptal on 10/11 and 11/12 (*i.e.*, in ix, xi, and xii).

SETAE: Slightly S-shaped chitinous bristles, 8 per segment, used by the earthworm to assist in locomotion. When extended, they act as an anchor in the substrate. The setae of each side are labeled *a*, *b*, *c*, and *d* and the corresponding ranks of setae are labeled *A*, *B*, *C*, and *D*. These positions are used as landmarks for other structures. For instance: "Spermathecal pores in *D*" means that the pores are in line with the *D* rank of setae (Figure 2).

Lumbricid species tend to have setal intervals *AB* and *CD* either very narrow or fairly wide relative to the distance between *B* and *C* (Figure 2a). The distinction between narrowly and widely paired is usually fairly easy to determine (but *cf. Eisenia*). If for some reason the setae are difficult to see externally, the difference can be discerned internally as relative distance between gaps in the longitudinal musculature. The setal intervals are measured behind the clitellum to avoid distortions in the genital regions.

SOMA: The body in general.

SPERMATHECAE: These are storage organs which receive sperm from the other member of a copulating pair. Spermatozoa are held in these organs until cocoon formation, when they are introduced into the cocoon as the worm is wriggling out of it (Stephenson, 1930). The spermathecae of the Lumbricidae are in the area of segments ix-xi and open in the intersegmental furrows. The dorsoventral position of the pore is of specific importance and was once thought to be generic. The pore is usually in line with setae *C* or *D* or is just lateral to the mid-dorsal line.

TESTIS SACS: Have been reported from *Lumbricus* and *Octolasion*. In *Lumbricus terrestris*, these are bounded by definite mesenteries which confine sperm and sperm morulae to the ventral portion of segments x and xi and contain the testes, male funnels, and openings of the seminal vesicles. This author has been unable to detect any such structure in western *Octolasion*.

TUBERCULA PUBERTATIS: Glandular pads or ridges in or near the ventral margin of the clitellum between setal ranks *B* and *C*, not associated with the setae (Figure 3).

TYPHLOSOLE: A variously modified ridge on the ceiling of the gut produced by an infolding of one or more layers of the gut wall. In all Lumbricidae, the typhlosole is present as an infolding of all layers of the gut wall. In other families the typhlosole may be absent, or an infolding of only the inner layer of the gut wall, which then encloses a vascular sinus. Most taxonomically useful characters of the typhlosole are in the anterior region, about segments xx-xxxv (Figure 7).

Figure 7. Cross-section of gut of *Aporrectodea trapezoides* in midbody, showing a T-shaped typhlosole with rounded face: **t**—typhlosole, **vg**—ventral groove. (The ventral groove is normally obscure in this species.)

VENTRAL INTESTINAL GROOVE: This is a longitudinal ciliated groove mid-ventral in the typhlosolar portion of the intestine, and is present in some species but absent in others. The function of this structure has never been examined and it is rarely reported in the literature (Figure 7).

II. KEYS

KEY DISTINGUISHING LUMBRICIDAE AND OTHER WESTERN EARTHWORMS

—Gizzard, thickened, muscular intestine wall, present in region of xvii; male pores on 15 or 13 in prominent male porophores in *BC* (or if male porophores not prominent then pigment a dark reddish-brown and prostomium tanylobic); clitellum anterior margin behind 18 ..... Lumbricidae

—Gizzard, if present, anterior to xv; male pores behind 16 *or* clitellum including segment anterior to 18 ..... Other Families (not treated in this work)

KEY TO THE SPECIES OF LUMBRICIDAE IN THE WESTERN UNITED STATES

A. EXTERNAL KEY

1 Tanylobic (but never with setae widely paired) 24
Epilobic (or if tanylobic, then with widely paired setae) 2

2(1) Nephropores obvious in a straight line (all at the same level) behind the male pores, setae separate, not paired 3
Nephropores obvious to obscure, alternating behind male pores, setae narrowly to widely paired or separate 6

3(2) Tubercula pubertatis absent ..... *Murchieona muldali*
Tubercula pubertatis obvious 4

4(3) Dark coloured, tubercula pubertatis on three segments (31-33) ..... *Dendrobaena octaedra*
Usually unpigmented but occasionally a murky gray-brown, tubercula pubertatis covering four or more segments ..... 5 (*Octolasion*)

5(4) Clitellum 29-34 tubercula pubertatis ($^1/_2$29)30-33($^1/_2$34) ..... *Octolasion cyaneum*
Clitellum 30-35, tubercula pubertatis ($^1/_2$30)31-34($^1/_2$35) ..... *Octolasion tyrtaeum*

6(2) Tubercula pubertatis clearly defined and starting behind segment 30 7
Tubercula pubertatis starting anterior to 31 or lacking 13

7(6) Tubercula pubertatis sucker-like on 31, 33, 35 ..... *Allolobophora chlorotica*
Not as above 8

8(7) Tubercula pubertatis on 33 and 34, genital tumescenes not on those segments 9
Tubercula pubertatis covering three segments, with or without division into two parts 10

9(8) Unpigmented, setae closely paired ... *Aporrectodea limicola*
Reddish pigment, setae widely paired ..... *Satchellius mammalis*

10(8) Tubercula pubertatis on 32-34, worm darkly pigmented *Aporrectodea longa*
Tubercula pubertatis on 31-33 11

11(10) Pigmented, tubercula pubertatis continuous — ..... *Aporrectodea trapezoides*
Unpigmented, tubercula pubertatis *usually* broken on mid 32 12

12(11) Genital tumescenes on 30, 32-34 ..... *Aporrectodea turgida*
Genital tumescenes on 30, 32, 34 ..*Aporrectodea tuberculata*

13(6) Tubercula pubertatis lacking, pigmented reddish, purplish, or brownish 14
Tubercula pubertatis present, usually definite in outline 17

14(13) Soma quadrangular, clitellum (20)22-29(30), setae very narrowly paired ..... *Bimastos tumidus*
Soma rounder, clitellum starts behind 23, setae various 15

15(14) Clitellum (25)26-31(32), setae widely paired, tubercula pubertatis occasionally present in (28)½29-30(31), vague in outline ..... *Dendrodrilus rubidus* f. *tenuis*
Clitellum starting about 24, setae narrowly paired 16

16(15) Prostomium nearly tanylobic (usually tanylobic), coastal forest species, purplish brown in life, *AB* > *CD* (check calciferous gland) ..... *Bimastos eiseni*
Prostomium always epilobic, reddish brown *AB* > *CD* (CD = 3/4 AB) (check calciferous gland characters) ..... *Bimastos parvus*

17(13) Tubercula pubertatis entirely anterior to 27, male pores usually on 13, quadrangular in x-section, green-brown to orange ..... *Eiseniella tetraedra*
Tubercula pubertatis entirely posterior to 27, male pores always on 15 18

18(17) Tubercula pubertatis 30-32, nephropores alternate regularly in *B* and *D*, pale reddish with unpigmented "epaulets" in 9-11, segment 1, and ventrum ..... *Dendrobaena attemsi*
Tubercula pubertatis not extending past 31 19

19(18) Tubercula pubertatis in 30-31, clearly defined, but often raised on ridges extending 29-32 20
Tubercula otherwise, at least partly into 29 21

20(19) Colour in narrow bands, with wide unpigmented intersegmental bands, segments generally more than 110, prostomium long-epilobic, sometimes tanylobic (check for bifid typhlosole and four pair of seminal vesicles) ..... *Eisenia zebra*
Colour more solid, segments generally less than 110 (but occasionally up to 130?), prostomium epilobic (check for lamellar typholosole and three pairs of seminal vesicles ..... *Eisenia hortensis*

21(19) Unpigmented, spermathecal pores large, obvious near mid-dorsal line, setae very narrowly paired .. *Aporrectodea rosea*
Pigmented (reddish), spermathecal pores very small or absent, setae less narrowly paired, worms with flat ventrum (creeping sole) 22

22(21) Tubercula pubertatis clearly on 28-30; spermathecal pores minute, near mid-dorsal line of 9/10 and 10/11, colour lacking in definite "epaulets" in 9-11 23
Tubercula pubertatis obscure, often lacking on one side, 28 or 29-30, sometimes 31; spermathecal pores not near mD, usually lacking, a sharp division between pigmented (reddish) dorsum and pale ventrum in 15 to 26, no pale "epaulets" ..... *Dendrodrilus rubidus* f. *tenuis*

23(22) Colour in definite bands covering about 3/4 of the length of each segment ..... *Eisenia foetida*
Colour over nearly the entire dorsum of each segment ..... *Eisenia andrei*

24(1) Tubercula pubertatis absent ..... *Bimastos eiseni*
Tubercula pubertatis obvious 25

25(24) Clitellum starts anterior to 30, segments fewer than 120, male porophores inconspicuous 26
Clitellum starts posterior to 30, segments more than 100, male porophores large 27

26(25) Tubercula pubertatis on 28-31, male porophores entirely lacking, usually more than 100 segments ..... *Lumbricus rubellus*
Tubercula pubertatis on 29-32, male porophores present but very faint, usually less than 95 segments ..... *Lumbricus castaneus*

27(25) Tubercula pubertatis on 33-36, usually more than 130 segments ..... *Lumbricus terrestris*
Tubercula pubertatis on 35-38, usually less than 130 segments ..... *Lumbricus festivus*

B. SOMATIC KEY

1 Prostomium epilobic, or if tanylobic, setae widely paired or separate 2
Prostomium tanylobic, setae narrowly paired 23

2(1) Calciferous sacs absent 3
Calciferous sacs present in x 8

3(2) Nephropores behind 15 in an obvious straight row; last hearts in ix; nephridial vesicles opening laterally (tubercula pubertatis 31-33) ..... *Dendrobaena octaedra*
Nephropores alternate between levels in or slightly above *B* to above *D*; last hearts in ix or xi; nephridial vesicles opening terminally 4

4(3) Nephropores alternate regularly between *B* and *D*; last hearts in ix; setae separate *AB* = *BC* = *CD* (behind clitellum) (tubercula pubertatis 30-32; spermathecae in *D*) ..... *Dendrobaena attemsi*
Nephropores alternate irregularly; setae various; last hearts in xi (spermathecae near mid-dorsal line) ..... 5 (*Eisenia*)

5(4) Typhlosole lamellar, not bifid (seminal vesicles three pair in ix, xi, xii; tubercula pubertatis 30-31) .. *Eisenia hortensis*
Typhlosole bifid (seminal vesicles four pair in ix, x, xi, xii) 6

9

6(5) Setae widely paired, *AB* slightly less than *BC* (tubercula pubertatis 30-31) ..... *Eisenia zebra*
Setae more narrowly paired, *AB* much less than *BC* (tubercula pubertatis 28-30) 7

7(6) Colour in obvious bands, confined to mid-segment on dorsum ..... *Eisenia foetida*
Colour nearly solid on dorsum ..... *Eisenia andrei*

8(2) Nephropores in a straight row above *B* behind male pores 9
Nephropores alternating between two levels, in or above *B* and in or above *D* 11

9(8) Setae closely paired; calciferous sacs projecting downward from dorsolateral oesophagus, lumen U-shaped, dicameral, chambers joined ventrally (clitellum 27-33; tubercula pubertatis absent) ..... *Murchieona muldali*
Setae widely paired or separate behind clitellum; calciferous sacs unicameral, opening as vertical slit in lateral oesophagus (clitellum starting behind 28; tubercula pubertatis prominent) ..... 10 (*Octolasion*)

10(9) *AB* larger than *BC* (clitellum 29-34; tubercula pubertatis (½29)30-33(½34)) ..... *Octolasion cyaneum*
AB = ca. *BC* (clitellum 30-35; tubercula pubertatis (½30)31-34(½35)) ..... *Octolasion tyrtaeum*

11(8) Nephridial vesicle sausage-shaped, without 180° bend at dorsal extremity 12
Nephridial vesicle with 180° bend at dorsal extremity (nephridia sometimes with glandular mesentery obscuring details) 13

12(11) Setae narrowly paired; typhlosole a simple lamella; soma tetragonal in x-section behind clitellum; colour green-brown to orange (male pores usually on 13, somes 15 or 12; female pores median to *A* on 14; clitellum 22-27 or more anterior) ..... *Eiseniella tetraedra*
Setae widely paired; soma not tetragonal; colour reddish; typhlosole with transverse ridges on the flanks (male pores always on 15; female pores lateral to *B* on 14; clitellum 31-36) ..... *Satchellius mammalis*

13(11) Typhlosole a lamella bearing paired lateral flaps, four pair per segment (tubercula pubertatis two pair on 33, 34) ..... *Aporrectodea limicola*
Typhlosole not as above 14

14(13) Typhlosole with transverse pits or clefts on median face on either side of a median ridge 15
Typhlosole not as above 17

15(14) Unpigmented (tubercula pubertatis 31-33, divided by furrow on 32; clitellar genital tumescences 30, 32, 34, not 33) ..... *Aporrectodea tuberculata*
(*Ap. icterica*, known from eastern Canada, has t.p.'s on (34)37-41(43) but otherwise keys to this point)
Pigmented 16

16(15) Usually less than 160 segments; extremely common (tubercula pubertatis continuous on 31-33; genital tumescences on 30, 32-34) ..... *Aporrectodea trapezoides*
Usually more than 160 segments; very rare in the West (tubercula pubertatis continuous on 32-34; genital tumescences on 31, 33-35) ..... *Aporrectodea longa*

17(14) Typhlosole T-shaped in x-section, with three to five longitudinal ridges at least anteriorly (ridges disappear posteriorly); without red pigment, colour various (but *cf. chlorotica*) 18
Typhlosole lamellar or simply bifid on ventral edge; pigment red to purple-brown 20

18(17) Ental limb of nephridial vesicle posterior; unpigmented 19
Ental limb of nephridial vesicle anterior; green, yellow, pink, or brown in life, green or colourless in preservation (tubercula pubertatis sucker-like on 31, 33, 35) ..... *Allolobophora chlorotica*

19(18) Nephridia with thick glandular mesentery covering and obscuring vesicle, vesicle much smaller than remaining nephridium; typhlosole with five (or three in part) nearly equal longitudinal ridges (spermathecae in *C*; tubercula pubertatis on 31-33) ..... *Aporrectodea turgida*
Nephridia without obscuring mesentery, vesicle nearly as large as entire nephridium; typhlosole with smaller median ridge nearly buried by large, flanking ridges (spermathecae near mid-dorsal line, pores conspicuous; tubercula pubertatis on 29-31) ..... *Aporrectodea rosea*

20(17) Setae widely paired; posterior lip of calciferous sac near 10/11 very common species (spermathecae occasionally present; clitellum (25)26-31(32)) ..... *Dendrodrilus rubidus* f. *tenuis*
Setae narrowly paired; posterior lip of calciferous sac in mid-x; species very rare in our area (spermathecae never present) ..... 21 (*Bimastos*)

21(20) Bead-like swelling in oesophagus in xi; prostomium usually tanylobic (clitellum 24-32 (33)) ..... *Bimastos eiseni*
Oesophagus not greatly swollen, slightly enlarged in xi-xii 22

22(21) Quandrangular in x-section posteriorly (clitellum (20)22-29(30)) ..... *Bimastos tumidus*
Round in x-section posteriorly (clitellum 24-30(32)) ..... *Bimastos parvus*

23(1) Typhlosole wrinkled-lamellar, without obvious clearly defined tranverse ridging (tubercula pubertatis absent, seminal vesicles in xi and xii only) ..... *Bimastos eiseni*
Typhlosole with closely spaced, clearly defined transverse ridges, alternating with a series of pits on median face of the typhlosole (tubercula pubertatis present, obvious; seminal vesicles in ix, xi, xii) ..... (*Lumbricus*)[6]

III. MAPS

The maps in this work, included with each species in the Descriptive Material section, are derived from several sources. The closed circles represent collections which have been examined by either Dorothy McKey-Fender or myself, and the identification of which we can verify. The open circles represent collections reported in the literature, usually in the references by Gates cited under the species, but also Smith (1917), Altman (1936), Reynolds (1977b) and Reynolds *et al.* (1974). I have no reason to doubt the identifications in most of these cases, but consider that the two major sources of information should be distinguished.

Irregular dark patches are the result of several collections being closely adjacent and therefore producing overlapping circles. The location of western states and provinces is illustrated in Figure 10.

IV. DESCRIPTIVE MATERIAL

LUMBRICIDAE

DESCRIPTION

Male pores on 15 (or 13). Eight rows of setae. Clitellum starts behind 18. A calciferous gland consisting of longitudinal tubules in the oesophagus wall of xi-xiv, opening in x or xi with or without

[6]Go to couplet 25 of EXTERNAL KEY.

the intervention of oesophageal diverticula (calciferous sacs). Dorsal pores (usually) present. An intestinal gizzard involving some or all of segments xvii-xx. Dorsal intestinal typhlosole involving all layers of the intestinal wall. Nephridial vesicles present.

IDENTIFICATION

The Lumbricidae can be distinguished from all other western families by the presence of an intestinal gizzard behind xvi. From all except some Sparganophilidae, they can be distinguished by the clitellum being posterior to 18. The Sparganophilidae lack a typhlosole and gizzard. Also unique among western taxa are the lumbricid type of calciferous gland (other taxa have unfused lamellae or diverticular calciferous glands) and the typhlosole which involves all layers of the gut wall.

Other western earthworm families will be treated in a subsequent work.

DISTRIBUTION OF THE LUMBRICIDAE

The Lumbricidae as a family are now distributed worldwide, with representatives recorded from every region of the globe, and are dominant in the moister regions of both temperate zones. Except for a few adventive species, however, the family is limited to a portion of the North Temperate Zone between the Great Plains of North America on the west and Japan on the east. The bulk of the species are native to southern Europe. At the eastern extreme, Japan has one native species (*Eisenia japonica*). Most other Japanese earthworms are Megascolecidae of Southeast Asian affinities. The eastern United States has 11 indigenous species in two genera, *Eisenoides* (2 spp.) and *Bimastos*. The latter is an assemblage of 9 parthenogenetic, athecal "species" which differ in clitellum position and ecology, but in little else. Most native species of that area are *Diplocardia* spp. (Megascolecidae *sensu* Jamieson; Ancanthodrilidae *sensu* Gates) which have affinities with the earthworms of Central America. No lumbricid earthworm has been found to be native in the western United States, despite statements to the contrary in the literature (Altman, 1936; Omodeo, 1956).

That a direct land connection (since broken by continental drift) occurred early in the Tertiary between Europe and North America is incontrovertible (Colbert, 1973). This is certainly the explanation for the presence of endemic Lumbricidae in North America. The long duration of an arid barrier between eastern and western North America is attested by major differences in the moisture-loving taxa of the two areas (*e.g.*, mollusks, Henderson, 1931). There is no need to invoke extinction to explain the absence of endemic Lumbricidae in the West.

The spread of the adventive Lumbricidae into the temperate zones of the world has, like any good adventure story, elements of fitness, luck, conquest, failure, and a great deal of exaggeration. Many species extended their range so quickly that even specialists believed them to be native to their newly acquired territories (Altman, 1936). Other workers (Michaelsen, 1903; Stephenson, 1930) spoke of the extermination of the native species by the younger, stronger Lumbricidae. The truth is somewhat different. At least in western North America, it is the alteration of native habitat, mostly coniferous forest, into anthropic habitat, largely farm, garden, and pasture, which has favored the rapid spread of species adapted to these habitats. Unaltered habitats still largely contain the original species, even where disturbance has been major but has not altered the habitat to anthropic type.

Before the turn of the century, Eisen (1894) was still able to find *Argilophilus marmoratus* (a native species) in manure piles near Sebastopol, California. This shows that at least some native species were able to enter new habitats, but their absence now shows that they were unable to compete there once the adventive Lumbricidae arrived (see Abbott, 1980). Six years later (Eisen, 1900), it was said to be "almost impossible" to find any but "common, European varieties" in manure piles and gardens.

Certain species have been introduced recently enough that their spread has been documented *Aporrectodea limicola* and *Bimastos eiseni (q.v.)* have apparently arrived within the last 20 years. The spread of the nightcrawler, *Lumbricus terrestris*, considered by so many to be synonymous with "earthworm," into McMinnville, Oregon, can be taken as a case in point. It was first introduced to Linfield College campus around 1932 by students who brought it from the Reed College campus in Portland, Oregon (J. A. Macnab, *in litt.*). Around the same time, it was introduced into the new lawn of the Oregon Mutual Insurance Building in downtown McMinnville. Even so, it was over 20 years later (1956?) before it reached the Fender farmstead, less than a mile from the campus through an old neighborhood with numerous houses and yards. This is hardly an aggressive colonizer, though it is now a dominant species on the place.

One could contrast the case of *Ap. limicola* (*q.v.*) which is abundant throughout Yamhill County, Oregon, 6 years after its first collection in this area, 13 years after the first Pacific Northwest record (Gates, 1972b).

Lumbricus castaneus (*q.v.*) became abundant on this same farmstead within two years after its first introduction to the place, probably in plants brought from Corvallis, Oregon.

Much more discussion of earthworm spread in North America can be found in several articles by Gates (1966, 1967, 1970, 1976a), though I believe he is over-pessimistic of the ability of endemic earthworms to have survived cold periods east of the Appalachians and his statement concerning endemic earthworms to the effect that "there are none in Canada" (Gates, 1970) is incorrect (Benham, 1892; McKey-Fender and Fender, 1982) as far as the West is concerned.

SYNONYMS

No formal synonymy is given in this work. The author's feeling is that a detailed treatment of what are, in most cases, 19th century obsolete names would serve more to confuse them than to enlighten. Complete synonymies may be found in the various works by Gates which are cited under the individual species. Confusion in the modern literature has been treated in this work under each species. Certain general facts, however, should be kept in mind. Nearly all of the lumbricid species here considered have at one time or other been included in the genus *Helodrilus* and *Allolobophra*, and many have been shifted among *Eisenia, Dendrobaena*, and *Allolobophora*. *Bimastus* and *Bimastos* are equivalent, as are *Octolasium* and *Octolasion*. A great many taxa treated here as species were at one time considered *formae* of *Eisenia* (= *Dendrobaena) veneta* such as *Dendrobaena veneta* var. *hortensis*. It is much more useful to remember the specific epithet, than the genera to which that species has been assigned.

Genus *Allolobophora* Eisen, 1873

Systematics

Allolobophora was once considered to contain the bulk of the species of the Lumbricidae, but has been pared down in recent times. Designation of *A. chlorotica* as the type species (Omodeo, 1956) left only it and a few European endemics in *Allolobophora s. str.* and, according to Gates (1972a, 1972b, 1975), left all other American "Allolobophora" species orphaned. While it is the opinion of this author that *Allolobophora* and *Aporrectodea* are perhaps not so distant as has been assumed by Gates *(loc. cit.)*, the two groups are certainly distinct and deserve recognition. Especially important to ecologists is the recognition that work done on *chlorotica* cannot be extrapolated to the *trapezoides* group and *vice versa*.

Allolobophora as seen in this country differs from *Aporrectodea* in having the calciferous sacs opening posteriorly in x and the ental limb of the U-shaped nephridial vesicle being anterior.

Other features of *Allolobophora* are the narrow setal intervals, four pair of seminal vesicles, irregularly alternating nephropores, and epilobous prostomium.

Allolobophora chlorotica (Savigny, 1826)

Identification

Adults of this species are easy to identify, possessing three pair of sucker-like tubercula pubertatis on 31, 33, and 35. No other western lumbricid possesses this characteristic. In addition, *A. chlorotica* has narrowly paired setae, U-shaped nephridial vesicles with the ental limb of the U anteriad, typhlosole with longitudinal grooves, and calciferous sacs in x. Each of these characters except the orientation of the nephridia would also fit *Aporrectodea turgida*, which has nephridial vesicles with the ental limb posteriad. Mature, living specimens of these two species bear no resemblance to each other, but preserved juveniles could in some instances be confused by an inexperienced observer.

Living *A. chlorotica* are usually green, but yellow, pink, and brown forms exist (in decreasing order of abundance) in the West. Genetic work has shown the colour forms to be simple genetic differences. When dug, these worms usually curl into a ring. This habit is a good characteristic for field identification, but a few specimens should be quickly checked with a hand lens for the three pair of tubercula pubertatis, as *Ap. rosea* (*q.v.*) will also do this, though the latter is unpigmented, and not likely to be confused by the experienced collector.

Distribution

This is one of the most widespread lumbricid species in the West, occurring in appropriate habitats wherever collectors have been, except in the extreme south (see Figure 8).

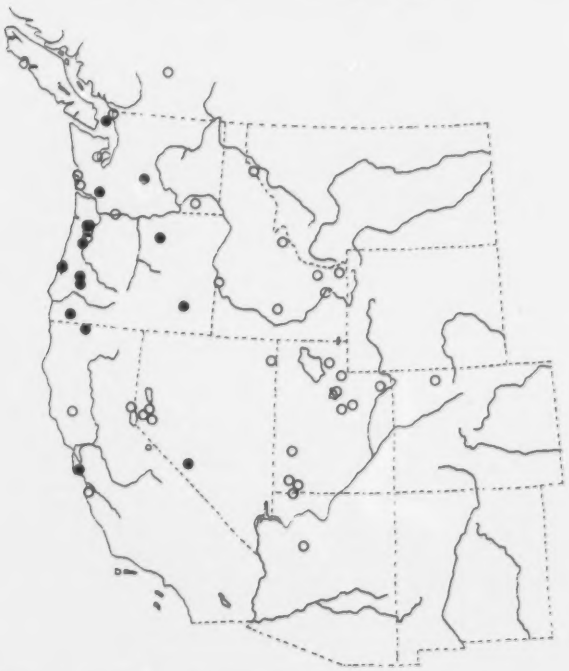

Figure 8. The known distribution of *Allolobophora chlorotica* in the western United States.

Habitat

Western records for this species are mostly from wet (or at least moist), highly organic soils. This species is usually not found in layers of pure organic material, but instead in areas where the soil itself has a high organic content and usually considerable clay. Usual sites are along clayey stream or pond margins and in gardens and barnyards. A collection from a gravel bar along the South Umpqua River was under stones in a clay-muck mixture which had been washed down by a slow trickle. This habitat also contained *Eiseniella* in the rockier portions and *Eukerria saltensis* (Ocenerodrilidae) in the muckier portions. One site was a stream warmed by the Darigold dairy plant in McMinnville, Oregon. Another was the wet soil of a greenhouse floor in Dayton, Oregon. The largest populations have been found in moist, manure-rich barnyard soils.

Graff (1953) gives the habitat as "moist mineral soil, by water . . . in arable land and gardens . . . also under pavement" (translated by D. McKey-Fender). Gerard (1964) notes also this species' presence in Lake Windermere "60 feet from shore, in 6 feet of water" and in subterranean water, but also in "semi-fixed dunes in Anglesey which dry out in the summer." We have no collections from dunes in the West. Gates (1972a) provides an exhaustive list, adding such habitats as caves and mines to the above.

Satchell (1955 *ex* Edwards and Lofty, 1972) termed *A. chlorotica* acid-intolerant and found that most specimens died after twenty-one hours on soil of below pH 4.4 (which they refused to enter). Bouché (1972) terms this species neutrophile and relatively acid-tolerant. He also says that the unpigmented form is more calcium-loving and that the green form is more hygrophilous.

Description (Gates, 1980; pers. obs.)

Colour in life variable, green, yellow, pink, brown, red, or slate. Length to 60 mm contracted, to 140 mm extended. Segment number 66 to 144, complicated by frequent regeneration. Three pair sucker-like tubercula pubertatis above *B* on 32, 33, and 35. Clitellum in region 29-37. Genital tumescences lacking or present in any of 9, 10 (*ab* or *cd*) or 27-83 (*ab* only). Male pores in a deep cleft of a large glandular tumescence on 15 which extends over part of 14 and 16. Spermathecal pores in *CD* area in 8/9-10/11. First dorsal pore 4/5 or 5/6. Nephropores moderately visible, irregularly alternating in three levels, above *B*, and *D*, and halfway between *D* and mD. Setae closely paired. Prostomium epilobic.

Well developed calciferous sacs enter oesophagus of x through vertically ellipsoid opening; lamellae of calciferous gland extend onto posterior and lateral wall of calciferous sacs. Crop with folded walls. Typhlosole beginning in xxi-xxii, anteriorly a dorsal lamella bearing a pair of lateral lamellae producing a cruciform x-section, appearing in ventral view to be longitudinally grooved. Ventral intestinal groove represented only by a ciliated strip. Nephridial vesicles U-shaped, ental limb anterior. Last hearts in segement xi. Extra-oesophageals join dorsal vessel in xii. Spermathecae three pair postseptal in *CD* in ix, x, and xi. Seminal vesicles four pair, anteseptal in ix and x, postseptal in xi and xii. Atrial glands from male porophore in xv and xvi.

Genus *Aporrectodea* Örley, 1885

Systematics

Aporrectodea in western North America includes a tightly knit group of four species: *trapezoides, turgida, longa,* and *tuberculata*. *Aporrectodea limicola* seems somewhat removed from the rest, but still closely related. Gates (1972b) also includes *Enterion roseum* Savigny, 1826 (= *Aporrectodea rosea*) in *Aporrectodea*, but I believe this species is no closer to *Ap. trapezoides*, the type, than is *Allolobophora chlorotica*.

The characters of *Aporrectodea* are: the vertical calciferous sacs opening in mid-x, the U-shaped nephridial vesicles with the ental limb posteriad, closely paired setae, and the nephridial mesentery large, glandular, and produced somewhat beyond the nephridial tubules. (This last character is *not* shared by *Ap. rosea*.)

Nomenclature

The earthworm literature contains many references to *Allolobophora caliginosa* Savigny, 1826) or sometimes *Helodrilus caliginosus*. This name has been applied to several taxa, most consistently to what are termed in this work *Ap. turgida* and *Ap. trapezoides*, but it is not possible at this date to determine what species Savigny originally meant by *Enterion caliginosum*. It could have been any of *Ap. trapezoides, turgida, tuberculata*, or *nocturna*, the statements of Tétry (1937) notwithstanding. *Allolobophora caliginosa* f. *typica* traditionally has been applied to what is here termed *Ap. turgida*, though not uniformly, and if the name *Al. caliginosa* were to be conserved, this would be the species meant. References to *Al. caliginosa* f. *trapezoides* may mean *Ap. trapezoides* as hefein defined, or may refer to aberrant specimens of *Ap. turgida*. Unqualified references to *Al. caliginosa* may refer to either species, and without further descriptive comments, are unusable. To avoid further confusion, ecologists should use the names given herein until and unless the International Commission on Zoological Nomenclature decides the status of *Enterion caliginosum*.

Lumbricus trapezoides Dugès, 1828 is similarly unsupported by a type specimen but at least according to Gates (1972b) can be uniquely characterized by the description. Cain (1955) argued for the suppression of *trapezoides* (since it has been used for two distinct taxa) in favor of *Allolobophora iowana* Evans, 1947 (*q.v.*) for which type specimens exist, but this suggestion has not been followed by any other author. For the present, we follow the numerous authors who have used the name *trapezoides* for this species. This also is a matter for the Commission to decide.

The main import of these controversies to the ecologist is that, no matter how well identified his own material may be, literature references to the same species cannot be trusted, unless sufficient description is given as well, or he is able to examine specimens of the other researcher's species. Exceptions are as follows: "*Al. caliginosa*" from Britain and the far north of Europe is probably in most instances (but not all) *Ap. turgida*. *Allolobophora trapezoides* or *Al. c.* f. *trapezoides* from the Mediterranean region or other hot regions is probably *Ap. trapezoides*, especially if reference can be found to dark pigment. *Allolobophora iowana* is always to be interpreted as the same as *Ap. trapezoides* as defined in references by Gates, Reynolds, or this author. Some European references to *Al. caliginosa*, especially in the older literature, may actually be *Ap. nocturna* or *Ap. tuberculata (q.v.)*.

It behooves the ecologist to state in publication not only the name of the species utilized, but the characters on which the identification is based, the reference used to identify the species, or the name or the authority who made the identification, and the location of well preserved (!) reference specimens so that the identification can be checked by other researchers. Without all of the above, a published set of experimental data, no matter how carefully derived, becomes almost totally useless! In this connection, Gates (1972a) notes that a researcher supposedly using *Lumbricus terrestris* was actually using an *Aporrectodea* sp!

Bouché (1972) described the new genus *Nicodrilus* with the type species *Enterion terrestris* Savigny, 1826 to hold what is here considered the core group of *Aporrectodea* Örley, 1885. A table of synonymy is appended below:

Bouché	Present Usage (after Gates)
Nicodrilus caliginosus caliginosus	*Aporrectodea turgida*
N. caliginosus meridionalis	*Ap. trapezoides*
N. c. alternisetosus	*Ap. tuberculata*
N. longus longus	*Ap. longa*

Aporrectodea limicola is not discussed by Bouché and perhaps is absent from France.

Aporrectodea limicola (Michaelsen, 1890)

Identification

Aporrectodea limicola can be distinguished externally as an unpigmented worm of medium size, with two pair of tubercula pubertatis on 33 and 34 and a series of genital tumescences in the region of the clitellum including 32 and 35 but *not* 33 and 34. Internally, it can be told by its distinctive typhlosole, which is a lamella which bears four pair per segment of lateral, semicircular flaps, together giving the impression of a "row of coins" stuck through a strip of cardboard.

Other corroborative features include U-shaped nephridial vesicles with the ental limb posteriad, vertically oriented calciferous sacs in mid x, and narrowly paired setae.

Distribution

Aporrectodea limicola was unknown in the western U.S. before 1969-70 when it was collected in four sites in both Oregon and Washington (Gates, 1972b). The first record of its occurrence in Yamhill County, Oregon, was in 1976 at a single locality west of McMinnville. In 1978 it was collected in Dayton. As of this writing, July 1982, it has become abundant in the wet clay along Cozine Creek in McMinnville, Oregon, and is present in other moist sites in the area. It would seem that its introduction into the Pacific Northwest is relatively recent (some time in the 1960's?) and that it is rapidly spreading into its preferred niche (see below) which was formerly occupied by *Al. chlorotica* and *Ap. turgida* (*q.v.*) (see Figure 9).

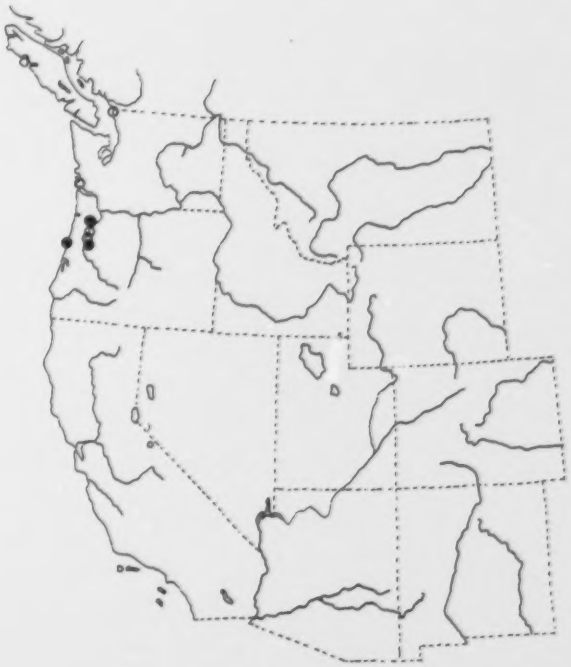

Figure 9. The known distribution of *Aporrectodea limicola* in the western United States.

Habitat

This species is found in mud of a high organic matter content and somewhat to very acid. A list of Oregon habitats for *Ap. limicola* shows the uniformity of their niche:

Under *Alnus rhombifolia* (white alder) in cattle-churned mud in a seep (Yamhill County).

In mud around roots of *Zantedeschia aetheopica* (calla lily) in a greenhouse (Yamhill County).

In mud and decaying vegetation (mostly grass roots) on a concrete pad on the edge of a land fill (Yamhill County).

In water-saturated Woodburn silty clay loam, under weedy grass and rotting apples under an apple tree (Yamhill County).

Among decayed leaves, sticks, and living grass roots in clay in the margin of Cozine Creek (Yamhill County).

Flood plain of the Calapooya River (Linn County).

In silty clay soil saturated by overflow from a faulty septic tank (Yamhill County).

Under chunks of wood and in wet mud along the seashore at Devil's Punchbowl State Park (Lincoln County).

Gerard (1964) gives the habitat of this species as "marshy and very wet soils, with a pH usually between 4.5-6.6; also from pasture and arable land." Gates (1957) reported material from a peat bog in Arnold Arboretum. Graff (1953, translated by D. McKey-Fender and W. Fender) says this species is in very wet and muddy (lehmigen) soil near water, also in "Auwäldern."

Description (Gates, 1957; pers. obs.)

Pigmentless. Flesh-colour anteriorly, grayish posteriorly. Length to 120 mm. Segments (83)100-130(146). Tubercula pubertatis two well developed pairs on segments 33 and 34 (often present as rudiments on adjacent segments). Clitellum on segments (28)29-35(36). Genital tumescences on all or some of 9-12, 29-32, and 35-38. Usually on at least 9, 12, 32, and 35, never on 33-34 (t.p. segments), occasionally present elsewhere. Male pores in a deep cleft of a glandular tumescence which extends into 14 and 16. Spermathecal pores in *CD* lines in 9/10-10/11. First dorsal pore in 4/5 (5/6). Nephropores very inconspicuous, alternating among several levels. Setae closely paired. Prostomium epilobic.

Well developed calciferous sacs in x, opening into oesophagus of segment x through a vertical slit, calciferous lamellae extending onto posterior wall of sac. Crop with folded walls. Typhlosole a dorsal lamella bearing lateral flaps, four pair per segment, giving the appearance of a row of coins held together by a string along the edge. A definite ventral groove is present opposite the typhlosole. Nephridial vesicles are long and narrow, straight anterior to the gizzard, becoming U-shaped posteriorly, ental limb posterior. Last hearts are in xi. Extra-oesophageals join the dorsal vessel in xii. Seminal vesicles four pair, anteseptal in ix and x, postseptal in xi and xii. Spermathecae two pair, anteseptal in ix and x, in *CD*.

Aporrectodea longa (Ude, 1885)

Identification

Aporrectodea longa is a large, pigmented worm. Its definitive external characters are the tubercula pubertatis covering segments 32-34, and a pattern of genital tumescences which includes *ab* of 9-11, 31, 33-35, but *not* segment 32. This pattern is the same as that for *Ap. trapezoides*, to which it is closely related, except that the *Ap. longa* clitellum, tubercula pubertatis, and clitellar g.t.'s are one segment posterior to those of *trapezoides*.

Corroborative characters include the narrowly paired setae, vertical calciferous sacs in x, nephridial vesicles U-shaped with the ental limb posteriad, and the typhlosole, which is roughly T-shaped with paired transverse clefts or grooves lateral to a median ridge. All of these characters are shared by *Ap. trapezoides* which, however, usually has fewer segments, (93)132-159(169), than *Ap. longa*, 146-222. Even worms with the above description and more than 160 segments should be classed as *Ap. longa* only if at least rudimentary t.p.'s and g.t.'s are present because of the scarcity of this species in the West (see below) and its similarity to *Ap. trapezoides*.

Distribution

This species is only known from three localities in western North America: Chaffee County, Colorado, 1953; San Francisco, California, 1968; and Victoria, British Columbia, 1950 (new record).

It seems possible, in view of the dates of these records, that *Ap. longa* is a recent introduction into the West and will continue to spread as have *Ap. limicola*, *Bimastos eiseni*, and *L. castaneus*. It is equally possible, however, that its range is limited by some feature of the environment (see Figure 10).

Figure 10. The known distribution of *Aporrectodea longa* in the western United States.

Habitat

Habitat notes are unavailable for the western records of *Ap. longa*, so possible habitats must be gleaned from the literature.

Gerard (1964) says that this species is "terrestrial, in cultivated soil, gardens, pastures, woodland, chalky soils, and particularly abundant in soil bordering rives and lakes." Continental European records (Graff, 1953; Ude, 1929) often treat *Ap. longa* together with "*Allolobophora terrestris*" (Savigny, 1926) [= *Ap. giardi* (Ribacourt, 1910) Gates, 1975] which further confuses the situation. Gates

(1972a, 1972b) lists recorded habitats for *Ap. longa*. These appear to be mostly moist, somewhat organic sites with or without a developed soil. The sites recorded appear on the average to be moister and more organic and with less necessity for soil than western sites for *Ap. trapezoides*, the nearest relative of *Ap. longa* in the West, and include such places as "cowyards, chicken yards, compost, humus, cow and other manure" as well as "flower beds," lawns, grassland, and pastures. The Vancouver Island specimen was taken with *Ap. tuberculata*, *Lumbricus rubellus*, and *Eisenia foetida* (*q.v.*) which again suggest a rather rich site. If our impressions gleaned from the literature are accurate, this may explain why *Ap. longa* is so abundant in glaciated New England (Gates, 1972b), whereas *Ap. trapezoides*, which lives in soil, predominates elsewhere in the United States.

Aporrectodea longa in Europe also has a northerly distribution, not including Italy or Spain, whereas *Ap. trapezoides* is more southerly. Temperature differences may therefore play some part in their distribution. Miles (1963 *ex* Gates, 1972a) gives the heat-death temperature of this species as 25.7°C (88°F). *Aporrectodea trapezoides* (*q.v.*) is alive and healthy in warm soils up to at least 80°F (23.5°C) in the West, but I know of no published heat-death figures for this species. It is commonly found, however, in greenhouses, next to heating pipes, in outflow from hot springs, and on south-facing slopes. A good side by side comparison of physiological and behavioral parameters in these two species would answer many of these questions. They are both large and vigorous, and should make excellent experimental subjects.

Bouché (1972) calls *Ap. longa* neutrophile, relatively acid-tolerant, and hygrophile. "This taxon is very frequent [in France] and is of particular interest because of its importance in the function of the ecosystem" (trans. by this author).

Description (Gates, 1972b); pers. obs.)

Pigmented, brownish. Length to 150 mm (contracted, probably to 200+ mm extended); 146 to 222 segments. Clitellum (26)28-35(36). Tubercula pubertatis on 32-34, without cross groove on 33. Genital tumescences on 9-11, 31, and 33-34. Male pores on 15. Spermathecal pores in *C* lines on 9/10 and 10/11. Dorsal pores usually begins about 12/13. Nephropores alternate irregularly between two levels, in *BC* and above *D*. Setae are narrowly paired. Prostomium epilobic, closed.

Some anterior septa thickened (6/7-11/12) especially 7/8-9/10. Calciferous sac is in mid-x, vertically oriented. Calciferous gland narrow. Gizzard asymmetrical, protruding into xviii dorsally but of xvii, 17/18 pushed back to approach 18/19 dorsally. Typhlosole with transverse slits on each side of a slightly elevated ridge on ventral face of T-shape, become smooth, simply T-shaped. Definite ventral groove present opposite the typhlosole. Thick glandular mass attached to dorsal portion of the nephridial mesentery is most noticeable part of nephridium. Nephridial vesicle U-shaped with ental end being posterior and ventral, mostly obscured. Last hearts in xi. Extra-oesophageal large, joining dorsal vessel in xii. Spermathecae two pair in x and xi at 9/10 and 10/11, or trans-septal, sessile, opening in *C*. Seminal vesicles sac-like, anteseptal in ix and x, postseptal in xi and xii. No testis sacs.

Aporrectodea trapezoides (Dugès, 1828)
(= *Allolobophora caliginosa* f. *trapezoides* in part)

Identification

Externally, mature specimens of *Ap. trapezoides* can be determined by being *pigmented* worms with tubercula pubertatis continuous on 31-33 (usually with a ventral lobe in 31), and genital tumescences on 9-11, 30, and 32-34 (lacking on 31). It is most likely to be confused with *Ap. turgida*, which has the same pattern of g.t.'s, and which differs in the t.p. only in the presence of a transverse groove on mid 32 separating it into two halves and being nearly pigmentless, traces of pigment on the anterior usually being invisible in preserved specimens. *Aporrectodea tuberculata* has t.p.'s like *turgida* but lacks g.t.'s on 33.

Distinction of *Ap. trapezoides* and *Ap. turgida* can be very difficult under some circumstances. Tubercula pubertatis of *Ap. turgida* sometimes lack the transverse groove, whereas those of *Ap. trapezoides* sometimes have it. In addition, preservation in alcohol can bleach the pigment of *Ap. trapezoides* and soften the t.p. of *Ap. turgida* so that the transverse groove is lost. In these cases, one must resort to internal characters.

The most obvious difference between *trapezoides* and *turgida* internally is in the typhlosole. In the former, the typhosole is convexly semicircular in x-section and has paired transverse pits or clefts on either side of the ventral face. The median strip, which is not crossed by these clefts, may or may not be raised into a ridge. The typhlosole of *Ap. turgida* has a flattened ventral face with three to five longitudinal ridges and no pits.

Another useful distinction is that both *Ap. turgida* and *Ap. tuberculata* are sexual species with highly iridescent male funnels. *Ap. trapezoides*, on the other hand, is parthenogenetic and produces little or no sperm on the male funnels.

The appearance of the *Ap. trapezoides* typhlosole varies considerably, enough so that this author once believed that several species were involved. It has since become evident that the differences are a result of diet, the pits becoming obscured in starved worms and even disappearing in a specimen starved for microtome sectioning.

Typhlosolar characters are further obscured by the poor preservation so common in specimens "fixed" only in alcohol (see Preservation).

Further internal characters of *Ap. trapezoides* are the nephridial vesicles U-shaped with ental limb posteriad and vertical calciferous sacs in x, common to all members of *Aporrectodea*.

Distribution

This species is found throughout the West wherever there is sufficient moisture. It is the most abundant and widespread of the western earthworms. This statement is based on the author's personal collecting experience as well as on records in the literature (see Figure 11).

Habitat

A true soil earthworm, this species is found in the western U.S. wherever there is suitable habitat. It easily predominates in pasture and rangeland with over 20 inches of annual rainfall, living in and feeding on the soil, but also feeding on the underside of "cowpies" or other organic debris. *Aporrectodea trapezoides* will aestivate in dry periods, but will remain active throught the summer in moist soil at stream margins and in seeps. This species does not live in heaps of organic materials but will inhabit thin layers of soil between cobbles and between rocks on cliff faces. Its presence or absence cannot be determined by surface castings, through it will cast on the surface occasionally, in Nebraska (Macnab, 1931—M.A. thesis) doing so mainly after freezes had destroyed the burrows.

This species seems to be unimpeded by temperature extremes, being found at 5000 feet in the Central Oregon Ochoco Mountains, as well as in warm (23.5°C) soil next to heating pipes in Oregon State University campus, in a greenhouse in Dayton, Oregon, on south-facing slopes, in soil wet by Ohanapecosh Hot Springs at Mt. Rainier, Washington, and with *Amynthas* (*Pheretima*) spp. in Louisiana. Often the ecotypes found in the warmer sites are almost black, contrary to the usual red-brown to gray-brown pigmentation.

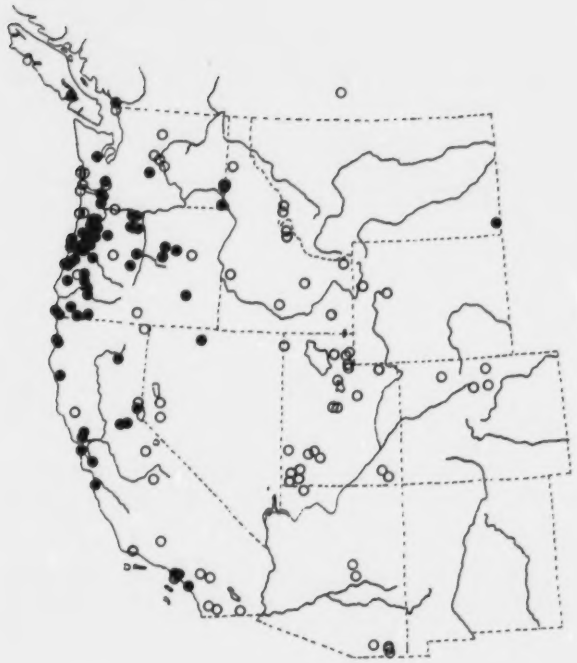

Figure 11. The known distribution of *Aporrectodea trapezoides* in the western United States.

Aporrectodea trapezoides is also present in oak and alder forest, on silted river flood plains, and in gardens and irrigated land, though in the latter areas it often is replaced by or in competition with other species.

Records for *Ap. trapezoides* in the literature are confused by the fact that both *Ap. turgida* and this species were for long submerged in a single species, *Al. caliginosa* (Savigny, 1826) (see *Apporectodea* Systematics). *Aporrectodea trapezoides* is very rare (if present) in England. Certainly this species is not represented by Gerard's (1964) key to British Lumbricidae. As noted above, each can mimic the genital characteristics of the other, and few authors, even those who recognize a distinction between the two species, use typhlosolar characters which bear the most obvious differences. In New Zealand, *Al. caliginosa* f. *trapezoides* is distinguished, as in England, *only* by tubercula pubertatis characters, despite the description of *f. typica* as being "pink anteriorly, greyish posteriorly" and with "no strongly thickened septa" (Lee, 1959). *Aporrectodea trapezoides* in the West is always pigmented and with extremely thick, strong septa anteriorly, so it seems likely that Lee did not have *trapezoides*, but simply a variant of *turgida* (but *cf.* Gates 1972b:27-29).

Description (Gates, 1972b; pers. obs)

Pigmented, reddish brown, gray-brown to black. Length 80-180 mm, extended to 220 mm. Segments (93)132-159(169). Tubercula pubertatis on 31-33, without a cross groove on mid-32. Clitellum usually 28-32. Genital tumescences 9-11, 30, 32-34. Male pores in mid-15 in cleft on porophores reaching into 14 and 16. Spermathecal pores in *C*, in 9/10 and 10/11. Dorsal pores begin in region 6/7-13/14. Nephropores alternate above *B* to above *D*. Setae narrowly paired. Prostomium epilobic, closed.

Septa 6/7-10/11 very thick. Calciferous sacs large, opening more or less in mid-x. Calciferous gland expanded somewhat in xi, less so in xii. Typhlosole with rounded ventral face with transverse pits on either side of a median ridge, not becoming longitudinally grooved posteriorly. Ventral groove very definite. Nephridia with glandular mesentery dorsally. Nephridial vesicle indefinite. U-shaped, ental limb shorter, posterior. Last hearts in xi. Extra-oesophageal joins dorsal vessel in xii. Spermathecae imbedded in septa 9/10 and 10/11. Four pair of seminal vesicles, anteseptal in ix and xi, postseptal in xi and xii. Testis sacs absent.

Aporrectodea tuberculata (Eisen, 1874)

Identification

Aporrectodea tuberculata, like *Ap. turgida*, has tubercula pubertatis on 31-33 with a transverse furrow on mid-32, but has a genital tumescence pattern of 9-11, 30, 32, 34 (lacking on *both* 31 *and* 33). It is unpigmented and has a typhlosole which, like *Ap. trapezoides*, bears a double row of *pits* (not clefts) on the flanks of the median face, but which, like *Ap. turgida*, becomes longitudinally grooved posteriorly.

As for the group, *Ap. tuberculata* has narrowly paired setae, vertical calciferous sacs in mid-x and U-shaped nephridial vesicles with the ental limb posteriad.

Distribution

This species has a generally northerly distribution in the Northern Hemisphere and in the West is usually found in cool areas, such as high mountains (*e.g.*, 1825 m in the Wallowa Mountains of Oregon). Although occasional specimens have been found in warmer areas such as in the Willamette Valley (Salem, Oregon) and Southern California (Santa Barbara), these are so few that they must be considered accidental (see Figure 12).

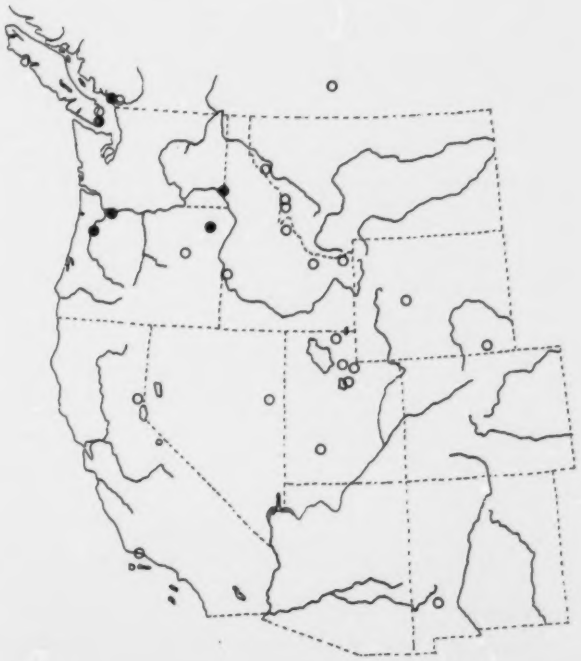

Figure 12. The known distribution of *Aporrectodea tuberculata* in the western United States.

Habitat

Very few collections of this species are represented in the McKey-Fender collection. Habitat records for these collections are, in Oregon, "rooty" soil on a bulb farm, Multnomah, County, in a streamside bog-meadow, Six-mile Meadow (1825 m elevation), Wallowa County, in wet soil in an aspen grove and meadow, Whorehouse Meadows, Grant County, and in a yard in Salem, Marion County. In eastern Washington (Pullman area), I have a single collection of this species from a northwest-facing canyon side under Douglas fir and various species of shrubs. The bulb farm, Salem, and eastern Washington sites were definitely from soil, and were similar to sites which might otherwise hold *Ap. turgida*. The Wallowa County site is a high alpine meadow with fairly organic soil, as is the aspen grove at Whorehouse Meadows.

Gerard (1964) gives only the habitat "pastureland" for this species, and cites only two localities in the British Isles. Gates (1972b) gives habitat notes with a series of collections. These include such diverse places as garden soil, lawns, woodland, streamside, detritus on bottom of a stream, and so forth. Apparently *Ap. tuberculata* is as varied in habitat as other *Aporrectodea* spp., though its range suggests that it prefers the cooler and moister end of the spectrum. Reynolds (1977a) summarized habitats for this species as "wet areas near streams and springs where was a large concentration of organic matter." "In east Tennessee . . . 75% of the time from ditches, or under logs or debris such as lumber" and ". . . being so common in gardens and fields is the species most likely to be dug for bait in much of Canada." (Reynolds *et al.*, 1974).

Description (Gates, 1972b; pers. obs.)

Length 59-150 mm. Segments (104)154-172(189). Unpigmented. Tubercula pubertatis on 31-33, divided by a cross groove on 32. Clitellum usually 27-35. Genital tumescences 9-11, 30, 32, 34, lacking on 33. Male pores at lateral end of cleft in porophores in mid-xv. Spermathecal pores in *C* in 9/10 and 10/11. Dorsal pores beginning in region of 9/10-13/14. Nephropores alternating above *B* to above *D*. Setae narrowly paired. Prostomium epilobic.

Septa 6/7-11/12 strongly thickened. Calciferous sacs vertical in mid-x. Calciferous gland slightly expanded in xi-xii. Typhlosole T-shaped, ventral face with transverse pits on each side of a median ridge, becoming longitudinally grooved posteriorly like *Ap. turgida*. A definite ventral groove opposite the typhlosole. Nephridia with glandular mesentery dorsally. Nephridial vesicle U-shaped, ental limb shorter, posterior. Last hearts xi. Extra-oesophageal vessel joins dorsal vessel in segment xii. Spermathecae sessile in x and xi adjacent to 9/10 and 10/11. Four pair of seminal vesicles, anteseptal in ix and x, postseptal in xi and xii. Testis sacs absent.

Aporrectodea turgida (Eisen, 1873)
(= *Allolobophora caliginosa* f. *typica*)

Identification

(see also *Ap. trapezoides*)

This species can be distinguished as unpigmented worms (except for very *slight* browning on the anterior, which is usually invisible in preserved specimens), with tubercula pubertatis on 31-33 but separated by a transverse furrow on mid-32 and a pattern of genital tumescences of 9-11, 30, 32-34.

Distinction of *Ap. turgida* and *Ap. trapezoides* is covered under the latter species.

Aporrectodea turgida and *Ap. tuberculata* can be distinguished by the latter lacking g.t.'s on 33 (present on 9-11, 30, 32, 34) and having a typhlosole with pits on the flanks of the median face, rather similar to *Ap. trapezoides*, and a segment number of 154-172, whereas *Ap. turgida* has an unpitted typhlosole and fewer segments (131-156). Otherwise the two species are rather similar.

Aporrectodea turgida also has the vertical calciferous sacs in x, and nephridial vesicles U-shaped with the ental limb posteriad characteristic of the *trapezoides* group.

Distribution

Aporrectodea turgida is present throughout the West, but is extremely abundant only in the moist coastal strip (see Figure 13).

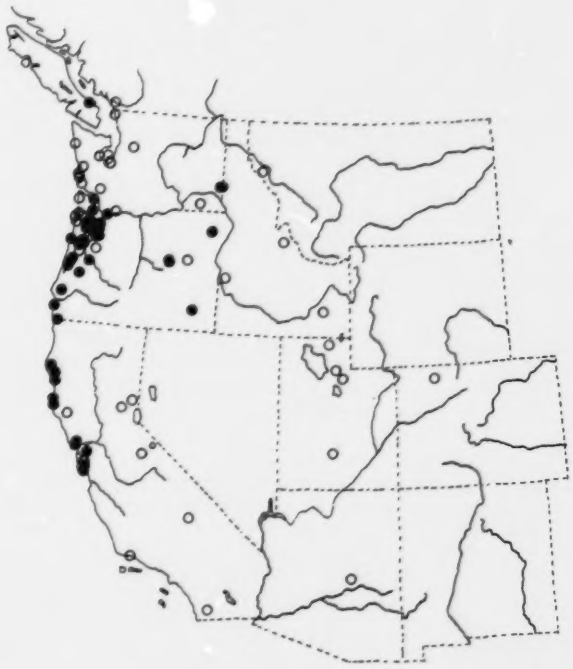

Figure 13. The known distribution of *Aporrectodea turgida* in the western United States.

Habitat

Aporrectodea turgida rivals *Ap. trapezoides* in the coastal strip for the title of "The Ubiquitous Worm" (Wormus ubiquitous), but its habitat is slightly different, somewhat moister and cooler, giving it a different distribution and, within a region, different areas of abundance. It is the dominant species in gardens and irrigated areas, bottomland along rivers, and moist roadside areas. *Aporrectodea turgida* will also survive under water. This is, however, a soil species like *Ap. trapezoides*. It casts primarily on the surface and may be responsible for most of the castings on the surface in lawns and gardens, though much of this is due to *Lumbricus terrestris*. *Aporrectodea turgida* does not, however, draw leaves into its burrows like the latter and so has clean piles of toothpaste-like castings, rather than the "trash piles" of *L. terrestris*. *Aporrectodea turgida* in the moister regions, such as the Willamette Valley, may be found almost anywhere with sufficient soil, in pastures, woodland, old roads, trash heaps, in dirt greenhouse floors, and near human habitations.

Gerard (1964:28) gives the habitat of *Al. caliginosa* (see *Aporrectodea* nomenclature) as: "found in most habitats, but particularly frequent in cultivated soil, in parks and gardens, and often numerically dominant in pastures. Also occurs on river banks in chalk soils and is absent from very acid peaty soils." Gates (1972a) lists habitats which, being unsorted, do not help a characterization. Reynolds (1977a) says "feeding and cast deposition occur below the

surface" and says the same of *Lumbricus terrestris* (*q.v.*), though my personal observations (see above) contradict this. Together, *Ap. turgida* and *L. terrestris* are probably the main surface-casting species in western Oregon.

Description (Gates, 1972; pers. obs.)

Length 60-85 mm contracted, to 200 mm relaxed. Segments (130)134-151(168). Unpigmented except for very slight browning in the extreme anterior. Tubercula pubertatis on 31-33, with a cross groove on 32, or sometimes undivided. Clitellum (27)28-34(35). Genital tumescences 9-11, 30, 32-34. Male pores in deep cleft on porophores on xv which extend into 14 and 16 in *AC* and are often joined ventrally. Spermathecal pores 9/10 and 10/11 in *C*. Dorsal pores begin in region of 9/10-14/15. Nephropores alternate irregularly from above *B* to above *D*. Setae narrowly paired. Prostomium epilobous.

Septa 5/6-11/12 thickened. Calciferous sacs open vertically in mid-x. Calciferous gland thicker in xi-xii. Typhlosole T-shaped, median face with two longitudinal grooves flanking a central ridge, and usually secondary grooves lateral to these, giving the appearance of three to five longitudinal ridges. A ventral groove definite opposite the typhlosole. Nephridia with thick dorsal glandular mesentery. Nephridial vesicle U-shaped, limbs of equal length, ental limb posterior. Last hearts in xi. Extra-oesophageal joins dorsal vessel in xii. Spermathecae sessile in x and xi adjacent to 9/10 and 10/11. Four pair seminal vesicles, anteseptal in ix and xi, postseptal in xi and xii. Testis sacs absent.

NOTE: The following species has been placed in *Aporrectodea* only for lack of a better place to put it, but, in the opinion of this author, does not belong there.

Aporrectodea rosea (Savigny, 1826)
(= *Eisenia rosea*)

Identification

Living mature *Ap. rosea* can be recognized by the striking orange clitellum, which may or may not be flared out laterally, and lack of pigment elsewhere on the body. Preserved specimens, if mature, have two (rarely three) pair of large, obvious spermathecal pores near the mid-dorsal line in 9/10 and 10/11 (and 11/12). Other identifying features of this species are the tubercula pubertatis on ½29-31, narrowly paired setae, and often genital tumescences on setal couples *cd* as well as *ab* on some segments anterior to the male pores. Internally, they have a typhlosole with two large flanking longitudinal ridges lateral to a narrow median longitudinal ridge, nephridial vesicles J-shaped, ental (shorter) limb posteriad, and calciferous glands vertical, opening in x through a crescentic slit.

Distribution -

This species is found throughout the West, but seems to be most frequently encountered in the warmer, dryer regions, where it takes advantage of very small patches of wet soil in an otherwise wormless environment (see Gates, 1967). It is not common in the Pacific Northwest, though it is abundant in towns and locally (see Figure 14).

Habitat

Northwest collections of this species have been in barnyards, lawns and gardens, greenhouse floors, in moist deciduous woods, pastures, in muddy seeps, and along streams. These habitats, while seemingly diverse, are nearly uniform in several respects. They are usually wet part of the year, though often bone-dry in summer, have a high clay content, and have a high influx of organic matter. Their habitat is similar in many respects to that of *Al. chlorotica* (*q.v.*) but differs in that *Ap. rosea* habitat is more likely to become dry in some part of the year. *Aporrectodea rosea* estivates randomly through the soil, often being found as pink coils in chambers only 15-30 cm from the surface in hard, dry clay. This species is able to take advantage of very small sites, probably being aided in this by its parthenogenetic reproduction, small size, ability to tolerate temporary drought, and a tendency to wander over the surface during wet weather. This species, along with *Lumbricus terrestris* and *Eisenia foetida*, is one of the most commonly observed surface travelers in Willamette Valley towns.

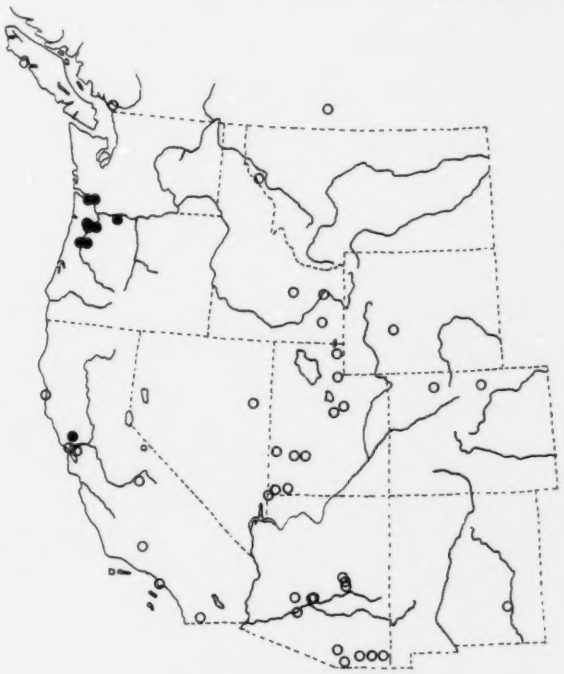

Figure 14. The known distribution of *Aporrectodea rosea* in the western United States.

Gerard (1964) lists habitats for *Ap. rosea* (as *Allolobophora rosea*) as "in pastures, gardens, woodlands, under leaves and stones, frequent on banks of rivers and lakes in limnic localities." Gates (1972a) notes this as "The only species widely distributed in virgin steppes of Russia, the only species found abundantly in forestless summits of mountains in the Caucasus" as well as giving an unsorted list of habitats. Reynolds (1977a) says "In soil under logs was the most common habitat of this species in Ontario." *Aporrectodea rosea* has been said to be a surface-caster (Thompson and Davies, 1974 *ex* Reynolds, 1977) but that habit can be neither confirmed nor denied by this author. Gates (1972a) gives a pH range of 4.9-8.0 for this species with no indication of the source of this information, or the methods used. *Aporrectodea rosea* was classed as acid-tolerant by Satchell (1955 *ex* Edwards and Lofty, 1972) who figured a pH range of *ca.* 4.6-7.0. Bouché (1972) calls this species neutrophile and relatively acid-tolerant, hygrophile, and living beneath the soil surface.

Systematics

This species has been placed in nine different genera, recently *Eisenia*, *Allolobophora*, and most recently (Gates, 1976b) in *Aporrectodea*. This is one indication that *Ap. rosea* is really not very close

to any other species. While it is now obvious from internal characters that *Ap. rosea* is part of the Allolobophora-Aporrectodea assemblage (Gerard, 1964; Gates, 1976b), it is doubtful that this species is much more closely related to *Aporrectodea trapezoides* than to *Allolobophora chlorotica*. It is placed here in *Aporrectodea* largely because there is no better genus presently to which it can be assigned, but ecologists should be aware that the final position of this important species has not been settled. One could predict a tenth generic name for *Ap. rosea* within ten to twenty years.

Description (Gates, 1974b; pers. obs.)

Unpigmented. Length to 80 mm. Segments in range of 100-150. Tubercula pubertatis on 29-31. Clitellum (23)25-32(33), often flared. Genital tumescences variable, often prominent on anterior segments on both *ab* and *cd* setal couples, a double row on *ab* through the clitellum, or absent. Male pores in small cleft of porophores which are joined ventrally and extend laterally to mid 14-16. Spermathecal pores prominent near mid-dorsal line of 9/10 and 10/11, rarely also in 11/12. Dorsal pores usually begin 4/5 or 5/6. Nephropores alternate irregularly between two levels, *B* and above *D*. Setae narrowly paired. Prostomium epilobic.

Septa thickened 6/7-10/11. Calciferous sacs opening in x through vertical crescentic slit. Calciferous gland slightly fusiform but not much expanded. Typhlosole T-shaped or Y-shaped, ventral face with two grooves flanking a small median ridge. A definite ventral groove is present opposite the typhlosole. Nephridia without glandular mesentary dorsally. Nephridial vesicle U-shaped, with ental limb shorter, posterior. Last hearts in xi. Extra-oesophageal joins dorsal vessel in xii. Spermathecae two pair in x and xi, adherent to 9/10 and 10/11, stalked. Seminal vesicles four pair, anteseptal in ix and xi, postseptal in xi and xii. Testis sacs absent.

Genus *Bimastos* Moore, 1893
(= *Bimastus*)

Systematics

The genus *Bimastos* is an assemblage of closely related parthogenetic clones which vary in clitellum position, somite number, and somewhat in exact niche. Though several European taxa have at some time or another been included in this genus, Gates (1969b) considers it to be exclusively American in origin, only *B. parvus* and its possible synonym and *B. beddardi* having been found elsewhere. *Bimastos muldali* (Omodeo, 1956) is now *Murchieona muldali*, *B. tenuis* is now *Dendrodrilus rubidus* f. *tenuis*, *B. icenorum* (described from England) is presently unidentifiable. *Bimastos eiseni* is of disputed status (Gates, 1968a, 1978a; also see under the species) but is considered by this author to be closely related to *Bimastos*, though somewhat distant from the American species.

The genus is characterized by the calciferous sacs being vertical in mid-x, the typhlosole lamellar or bifid ventrally, the nephridial vesicles U-shaped with the ental limb anteriad, setae narrowly paired, seminal vesicles in xi and xii only, and no spermathecae. If *B. eiseni* were excluded, one could add prostomium epilobic; calciferous gland not swollen greatly in any segment, somewhat fusiform in xi-xii; and ventral intestinal groove absent.

Bimastos parvus (Eisen, 1874)
[? = *Bimastos beddardi* (Michaelsen, 1894)]

Identification

This species is likely to be confused with the occasional epilobic speciment of *B. eiseni* which, however, has a bead-like enlargement of the calciferous gland in xi. It also may be confused with *Dendrodrilus rubidus* f. *tenuis* which has widely paired setae, but which are often difficult to see. Single specimens should be considered suspect without dissection.

Bimastos tumidus is distinguishable by its more anterior clitellum (20)22-29(30) and quandrangular x-section. *Bimastos parvus* was described with a clitellum from 24-30 and *B. beddardi* was erected for specimens with a clitellum extending to 32. These have since been synonymized and are treated together here, but Smith (1917) regarded them as separate species with differing habits and morphology. Reynolds *et al.* (1974) also regarded these as separate species.

Distribution

Bimastos parvus has been obtained only from a few sites in the West and Gates (1967) has said that "Large populations of *parvus* have not been found anywhere," though this is contrary to the experience of Macnab in Nebraska (see below). *Bimastos parvus* (and *beddardi*) have not been reported from the Northwest since 1900 (Michaelsen, 1900) and even this may have been erroneous (see Identification) (see Figure 15).

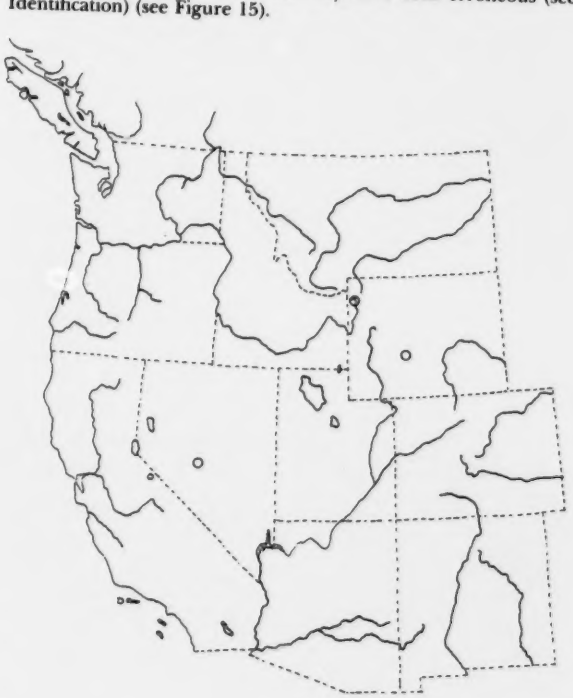

Figure 15. The known distribution of *Bimastos parvus* in the western United States.

Habitat

Smith (1917) gives the habitat of *B. beddardi* as "from wet situations and in decaying logs, stumps, or moss" and suggests that *B. parvus* is from higher and dryer situations. Gates (1972a), who considers the two species to be synonymous, gives a list of habitats, most of which appear to be high organic matter sites. Gerard (1964) gives the habitat as "decaying logs, stumps, or in moss" (perhaps a direct quote from Smith?). We have a specimen from Louisiana from a mixture of rice hulls and clay. Reynolds *et al.* (1974), in Tennessee, collected *B. parvus* from logs, debris and ditches. They reported *B. beddardi* from logs and dumps.

The best description of *B. parvus* habitat available to this author is by Macnab (unpublished M.A. thesis, 1931, University of Nebraska) and this is quoted below *verbatim*:

Helodrilus parvus. This has a rather specialized distribution but nevertheless a wide one. It is a very short worm averaging 50 mm in length by 1½ to 2 mm in diameter, of a brown or reddish color, and with a clitellum on the 24th to the 30th somites. The clitellum is very prominent. Some specimens show a tendency to rings on each segment similar to *H.* (A) *foetidus*. On each of the last few posterior segments a small yellow spot is almost invariably present. These worms were collected in great numbers from an old manure pile near the Burlington brick yards southwest of Lincoln. They were also found in horse manure gathered from the pasture at the agricultural college in east Lincoln. Other specimens were found in woods along Salt Creek west of the penitentiary at Lincoln; on the Kent farm north of Table Rock, Pawnee County; in a dried swamp bed among roots of a tall coarse grass and reeds; and in the thin layer of sandy humus and beneath pieces of cow dung along the bottom land of the Elkhorn River new Ewing, in Holt County. Here, as in other places, it would be very easy to explain their introduction with the manure of stock. At Ewing it probably indicated a case of succession. The sandy soil of this locality yielded no other species and it is probable that as the land became settled they either moved up the stream following irrigation and the bottom lands or else they were introduced as worms or cocoons in manure carried there for fertilizing the newly reclaimed soil. It would be very interesting to follow down this stream and see whether a succession of worms in the sandhill region might be discovered. The other localities all point to the conclusion that these worms find their optimum environment in moist soil richly provided with undecomposed or decomposing organic matter chiefly of plant origin. They were never found in clay soil unless abundantly provided with humus in the early stages of decay and never in pasture land unless irrigated, near some barnyard, or littered with dung of horses or cattle. They were always found near the surface and even in freezing weather did not seem to go deep in the ground. Evidently, either being resistant to extreme cold or taking advantage of the heat of decaying humus, they have never formed the habit of burrowing deep to escape freezing temperatures.

The absence of *B. parvus* in the Pacific Northwest, despite intensive collecting, is puzzling. It is unlikely that this species was never introduced into this area (but *cf. Ap. limicola*). More likely is the possibility that *B. parvus* is unable to tolerate some aspect of the Pacific Northwest climate. This certainly would not be severe winter cold for a species which thrives in Nebraska, but could be the cold winter rains. Manure piles in the Pacific Northwest cannot remain warm through the winter here unless covered, whereas in the drier Nebraska winter some of this heat might not be lost. A perhaps more logical possibility could be a requirement for a high electrolyte content of its substrate, again present in manure but quickly lost in wet climates.

Description [based on Nebraska specimens from the Macnab collection and Smith (1917)]

Small worms to 70(?) mm. Segments 85-111 (66-97 for *beddardi*). Colour reddish-brown. Body round in x-section. Tubercula pubertatis absent. Clitellum 24-30 (*parvus*) or to 32 (*beddardi*). Genital tumescences absent. Male pores in transverse slits on small round porophores confined to 15. Spermathecal pores absent. Dorsal pores start 5/6. Nephropores alternate irregularly between two levels, in *B* and above *D*. Setae narrowly paired. Prostomium epilobic, open.

Septa 6/7-10/11 very slightly thickened but all delicate. Calciferous sacs small, vertical in posterior x. Calciferous gland fusiform in xi-xii, not especially large. Typhlosole at first lamellar then becoming bifid ventrally (Y-shaped). No ventral groove opposite typhlosole. Nephridia without glandular mesentery dorsally. Nephridial vesicle U-shaped, ental limb slightly longer, anterior. Last hearts in xi. Extra-oesophageal narrow, joining dorsal vessel in xii. Spermathecae absent. Seminal vesicles two pair, postseptal in xi and xii. Atrial glands present. Testis sacs absent.

Bimastos tumidus (Eisen, 1874)

Identification

See *B. parvus*.

Distribution and Habitat

This species was until recently represented in the McKey-Fender collection by two samples supposedly from California (Calaveras County) caves. A recent collection trip into that area yielded two specimens from in and under manure but none from the several caves visited.

Gates (1956) recorded, without ecological data, a single specimen from Tamalpais, Marin County, California, but otherwise all records have been from the eastern United States, its native range (see Figure 16).

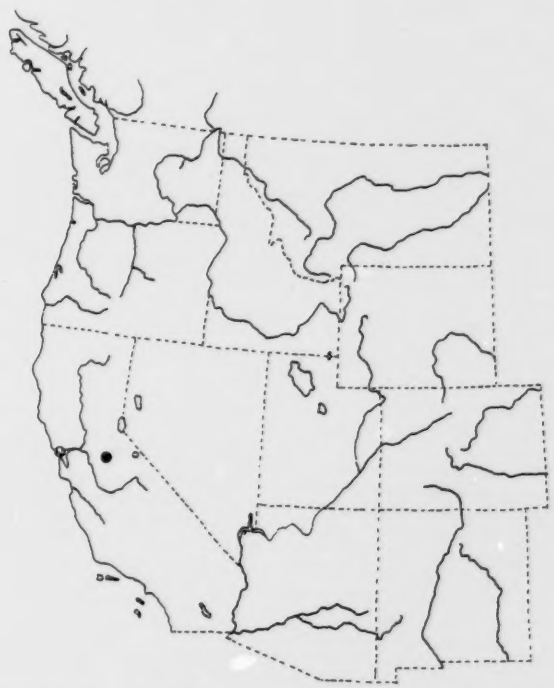

Figure 16. The known distribution of *Bimastos tumidus* in the western United States.

Gates (1959) recorded *B. tumidus* from several eastern caves and (1956) also from such habitats as "under logs in moist river bottom forest" in Louisiana, in "sawdust" in Virginia and "in and near ash of sawdust pile" in Louisiana. Smith (1917) under the name *Helodrilus (Bimastus) gieseleri* var. *hempeli*, said that it is "ordinarily found under the bark of decaying logs or in the rotten wood." In the Pacific Northwest this habitat is usually filled by *Dendrodrilus rubidus* f. *tenuis* which was once considered to be a species of *Bimastos* and which resembles that genus in habitus.

Description (Smith, 1917; Gates, 1956; pers. obs)

Small worms with tetragonal x-section posteriorly. Length to 40 mm contracted. Segments 81-122. Colour reddish? purplish-brown? Tubercula pubertatis absent. Clitellum (20)22-29(30). Gen-

ital tumescences absent. Male pores in slits on small porophores on 15. Spermathecal pores absent. First dorsal pres at 5/6. Nephropores alternate irregularly between two levels, just above *B* and above *D*. Setae very closely paired. Prostomium epilobic.

Septa not thickened anteriorly. Calciferous sacs vertical in posterior x. Calciferous gland slightly larger in xi-xii. Typhlosole lamellar at first, becoming expanded (or bifid?) ventrally. No ventral groove opposite the typhlosole. Nephridia without glandular mesentery. Nephridial vesicle U-shaped, ental limb longer, anterior. Last hearts in xi. Extra-oesophageal? Spermathecae absent. Seminal vesicles two pair, postseptal in xi and xii. Atrial glands visible in xv. Testis sacs absent.

NOTE: The following species is generally placed in *Bimastos*, but, in the opinion of this author, does not belong there, nor in any other generally recognized genus.

Bimastos eiseni (Levinsen, 1884)
(= *Lumbricus eiseni*)

Identification

From *Lumbricus*, *B. eiseni* can be easily distinguished by its lack of: tubercula pubertatis, spermathecae, enlargement of the calciferous region in xii, seminal vesicles in ix, and the distinctive transverse grooving of the typhlosole of *Lumbricus*. From other Lumbricidae, it can be distinguished by its (usually) tanylobic prostomium and bead-like enlargement of the oesophagus in xi. An occasional specimen has an epilobic prostomium and, except for the enlarged calciferous gland, could be mistaken for *B. parvus*.

Distribution and Habitat

Pacific Northwest collections for this species have been almost all from moist coastal areas or the Coast Range forest in Oregon, Washington, and Alaska (Reynolds *et al.*, 1974). One collection from a cool greenhouse on the Oregon Coast was from potting soil of which decayed leaf mould from a maple (*Acer macrophyllum*) grove was a major component. Other collections have been from such sites as along a small stream under mixed *Alnus rubra* (red alder) and *Acer macrophyllum* (bigleaf maple), in a pile of pine needles under *Pinus contorta* (shore pine) in a coastal deflation plain, under *P. contorta* in old sand dunes, and in moss on a stone in the Millicoma River (near Allegany, Coos County, Oregon). Comparison of the sites suggests that these worms require cool, even temperatures, high rainfall, an acid medium, and high amounts of organic matter, as well as, perhaps, heavy shade. The one inland collection was in company with another acidophile, *Dendrobaena attemsi*, in a cool greenhouse in Yamhill County, Oregon (see Figure 17).

Gerard (1964) states that *B. eiseni* "often is one of the dominant species in moorland and bog soils; also found under stones and decaying leaves, and in moss." Bouché (1972) says they are preferentially acidophile and strongly acid-tolerant, and live in a clearly organic medium (translated by this author).

Systematics

Levinsen's *eiseni* has been placed in *Lumbricus*, *Allolobophora*, *Dendrobaena*, *Eisenia*, and most commonly *Bimastos*. Gates (1968a, 1978a) returned this species to its original genus, *Lumbricus*, on the basis of its calciferous gland. Despite some similarities, notably the enlarged, bead-like calciferous gland and the tanylobic prostomium (*cf.* descriptions of *Lumbricus* and this species), *B. eiseni* is certainly not part of the very homogeneous *Lumbricus* assemblage. On the other hand, *B. eiseni* is very difficult to separate, even by internal characters, from *B. parvus*, the prostomium occasionally being epilobic. The most reliable differentiation is the bead-like swelling of the oesophagus in xi of *B. eiseni*.

Figure 17. The known distribution of *Bimastos eiseni* in the western United States.

Placement of an obviously European species, *B. eiseni*, in an obviously American genus, *Bimastos*, requires some justification, especially a parthenogenetic "species" which has been presumed to be a degraded "morph" of some other species (Gates, 1972a). The similarity of *B. eiseni* and *B. parvus*, however, in setal spacing, nephridial vesicles, calciferous sacs, and the habitat bespeak a reasonably close relationship which should not be ignored. Perhaps *B. eiseni* will be placed into a distinct genus in the future, but until then less damage is done to the known relationships by leaving it in *Bimastos* with the caution that it is somewhat removed from the rest. Bouché's placement of this species in "*Eisenia* s. lat.," while a poor place for it, shows that this species is not close to any of his other genera.

Description (Gates, 1968a; pers. obs.)

Subcircular to vaguely quadrangular in x-section. Colour and size very similar to *Lumbricus castaneus* or *rubellus*, but with a more purple cast. Length 20-75 mm. Segments 75-112. Clitellum usually 24-32(33), somewhat variable. Tubercula pubertatis absent. Male pores in small cleft of a glandular tumescence restricted to 15. Spermathecal pores absent. Dorsal pores start at 5/6. Nephropores alternate irregularly between two levels, slightly above *B* and well above *D*. Setae closely paired. Tanylobic, occasionally long-epilobic.

Anterior septa not or only very slightly thickened. Calciferous sacs short, sessile evaginations of the oesophagus wall in x, the sac and its vertical opening involving nearly the full height of the oesophagus; a large branch of the extra-oesophageal vessel joins the dorsal vessel in x after passing up the side of the oesophagus just anterior to and adherent to the calciferous sac (*cf.* this feature in *Lumbricus*). A single bead-like swelling of the oesophagus in xi, a very slight swelling in xii, xiii-xiv much reduced. Typhlosole an irregularly wrinkled lamella. Ventral groove opposite the typhlosole in xxviii-xxxvi. Nephridial vesicles U-shaped, the ental limb

longer, anterior. Last hearts in xi. Extra-oesophageal joins dorsal vessel in both x and xii. Spermathecae absent. Seminal vesicles two pair, postseptal in xi and xii. Atrial glands in xv, with transverse cleft. Testis sacs absent.

Genus *Dendrobaena* Eisen, 1874

Systematics

Dendrobaena has included a great variety of unrelated species including several treated here as *Dendrobaena attemsi, Dendrodrilus rubidus, Eisenia hortensis,* and *Satchellius mammalis* (*D. rubida, D. veneta hortensis, D. mammale*). Of the western species, only *Db. octaedra*, the type, can remain in this genus, and it is clearly unrelated to any other western taxon, except *Octolasion* spp. (Fender, 1982) and even these are not very close. The unique ocarina-shaped nephridial vesicles (see Terms) are shared only by the latter genus, which, however, possesses calciferous sacs.

Dendrobaena octaedra (Savigny, 1826)

Identification

Dendrobaena octaedra can be recognized by its dark colour (metallic purple-brown), straight series of nephropores above widely paired setae, and tubercula pubertatis on 31-33 (3 segments).

Internally it lacks calciferous sacs and has nephridial vesicles which open laterally (ocarina-shaped). This combination of characters is shared by no other western species.

Distribution

This species is very sporadically encountered in the West (see Figure 18).

Figure 18. The known distribution of *Dendrobaena octaedra* in the western United States.

Habitat

Specimens in our collection are from *Sphagnum* bogs in Washington, wet soil under greenhouse benches in Dayton, Oregon, and along a small polluted stream in Corvallis, Oregon. In addition, we have records from boggy soil around *Dodecatheon* roots in Alaska and from the Golden Gate Park arboretum. The sites personally collected by this author were wet and with abundant organic matter. In addition, the *Sphagnum* bog was very acid and the other sites were probably only somewhat less so.

Gerard (1964) says that this species "together with *B. eiseni*, is often dominant in wet moorland habitats." Gates (1972a) gives a long list of reported habitats which are so various as to be almost uncharacterizable but in the majority are probably moist, acid, high organic matter sites. Gates states that neither this species, nor *Dd. rubidus*, have been found in greenhouses, but both have been found in that habitat by this author. Gates also gives a pH range of 3.0-7.7 for *Db. octaedra*. Satchell (1955 *ex* Edwards and Lofty, 1972) calls *Db. octaedra* acid-tolerant and in his table gives a pH range of about 3.6-4.8. Heléne Lundkvist (1981, personal communication) notes that *Db. octaedra* is one of the few earthworms inhabiting blanket bogs under *Pinus sylvestris* in Sweden. Her sites had a pH range of 4.0-4.6 (6.1 limed) (Lundkvist, 1981).

Description (Gates, 1974a; pers. obs.)

Small worms round in x-section. Length to 50 mm. Segments 46-110. Colour purple-brown dorsally, red as seen in the muscle layers. Tubercula pubertatis narrow, lateral to *B*, in 31-33. Clitellum 29-33(34). Genital tumescences near male pore segments (15-17) and in clitellar region, *b* of 31-33 associated with genital setae. Spermathecal pores minute in area of *D*, 9/10-11/12. Dorsal pores begin in region of 4/5-8/9. Nephropores obvious, in a straight series just above *B*. Setae widely spaced, not paired, *DD* interval very narrow. Prostomium epilobic.

No septa especially thickened. Calciferous sacs are absent. Calciferous gland segmentally expanded in xi and xii, preceded by a short unexpanded portion of 10/11. Typhlosole round in x-section, but with a differentiated ventral face. Ventral groove opposite typhlosole entirely lacking. Nephridia without glandular mesentery. Nephridial vesicles opening laterally into *B*. (ocarina-shaped). Last hearts in ix. Extra-oesophageal joins dorsal vessel in ix or x. Spermathecae three pair in ix-xi at 9/10, 10/11, 11/12, stalked. Seminal vesicles three pair in ix, xi, xii. Atrial glands visible internally. Testis sacs absent.

Dendrobaena pygmaea (Savigny, 1826)

On January 6, 1984, subsequent to submission of this paper for publication, I found a single specimen of *Dendrobaena pygmaea* (Savigny, 1826) on the grounds of the Arboretum, Golden Gate Park, San Francisco, California. This is apparently the first North American record for this species. Examination of this specimen and reference to the literature have yielded the following information of potential use for researchers. Due to time constraints, I have not been able to include this species in the keys.

Identification and Description (Bouché, 1972; pers. obs)

Dendrobaena pygmaea has a saddle clitellum covering segments 33-37, separate (unpaired) ambulatory setae, and prominent nephropores which are in a straight series just above *B*. The form represented here appears to be that called *D. pygmaea cognetii* Michaelsen, 1903 by Bouché (1972) which lacks spermathecae and tubercula pubertatis, but *D. pygmaea pygmaea* possesses three pair of spermathecae and has tubercula on 35-37. The Golden Gate Park specimen has pale reddish pigment anteriorly, is 21 mm long

and has 99 segments. It has a prominent ridge in *BC* which extends from the male porophore in 15 to the clitellum. Dorsal pores are present from 7/8, though this is not supposed to be usual for the species. The prostomium is epilobic.

Internally, this specimen has the septa uniformly thin. The calciferous gland is swollen segmentally in xi-xiii and terminates anteriorly in a transversely oriented fold in mid-x which greatly resembles a rudimentary calciferous sac. The typhlosole is round in x-section. A ventral intestinal groove is present opposite the typhlosole. The nephridial vesicles are "ocarina-shaped", *i.e.* opening laterally as in *D. octaedra*. The last hearts are in xi. The seminal vesicles are post-septal in xi and xii. Spermathecae are lacking. Atrial glands can be seen internally in xv. Testis sacs are absent.

Habitat

The extremely small size of this species makes it unlikely to be collected by most people. I cannot reconstruct the exact habitat of the Golden Gate Park specimen for the very reason that it was discovered later in a large collection of specimens of other species from miscellaneous sites. However, most of the sites collected were heavily mulched areas under shrubs and were presumably quite acid in the layers inhabited by the worms. European collections (Bouché, 1972) have been in acid, organic sites.

Systematics

The affinities of this species are quite obviously with *Dendrobaena octaedra* and *Octolasion* which share the ocarina-shaped nephridial vesicles and obvious nephropores in a straight series. The form of the calciferous gland in *D. pygmaea* suggests a transitional form between those with and without calciferous sacs.

NOTE: The following species has traditionally been placed in *Dendrobaena* but, in the opinion of this author, does not belong there, nor in any other generally recognized genus.

Dendrobaena attemsi Michaelsen, 1902

Identification

"*Dendrobaena*" *attemsi* can be identified externally by the unpaired setae, *aa:ab:bc:cd:dd* = 14:10:10:10:26 (C = 100). Clitellum (28)29-33(34) with tubercula pubertatis on (29)30-32(33) and the nephropores alternating with great regularity between levels *B* and *D*.

Internally this species lacks hearts in x and xi, lacks calciferous sacs, has a lamelliform or ventrally grooved typhlosole, and has nephridial vesicles which are straight, vertically oriented, and with a recurved ventral terminus rather like a J with the hooked end ventrad. This vesicle type is unique among the western Lumbricidae.

Spermathecae are two pair in ix and x, opening in *D* in 9/10 and 10/11. Seminal vesicles are in ix, xi, and xii. Testis sacs are absent.

Distribution and Habitat

D. attemsi has been found in two locations in the West. It was in moderate abundance under pots and wooden flats in a *Sphagnum* peat and vermiculite potting mix in a cool greenhouse in Dayton, Oregon (Fender, 1982), in association with *Dendrodrilus rubidus* f. *tenuis* (*q.v.*), and was abundant in bark mulch under and around established Mugo Pines (*Pinus mugo*) in a garden in Auburn, Washington (Fender, unpubl.) (see Figure 19).

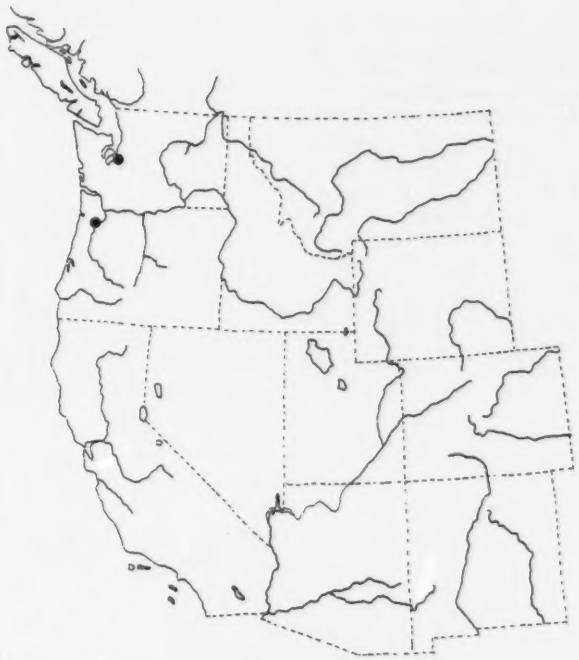

Figure 19. The known distribution of *Dendrobaena attemsi* in the western United States.

Few references to this species exist in the literature available to this author. Graff (1953) gives this species' habitat as "Humus der Laubwälder" (deciduous forest) and also says that it is found in "Gewächshäuser und Gärtnereibetriebe" (greenhouses and nursery operations) and is restricted to such places in Germany and Bohemia. Its natural range is "from the Caucasus over the Balkan peninsula to Austria" (translated by this author). Heugens (1969 *ex* Edwards and Lofty, 1972) used *D. attemsi*, along with other species, in experiments on the decomposition of pine litter. Gates (1974a) reported on specimens of *D. attemsi* from an unknown, but possibly American, source.

Systematics

The species treated here is certainly not a *Dendrobaena*, but has no other available genus so far as this author can tell from the available literature. Bouché (1972) described as *attemsi* a species which, though it fits the above in many respects, supposedly has a straight series of nephropores above *B*, has hearts, though reduced, in x and xi, and has dorsal pores anterior to the clitellum. The lack of nephropore alteration in Bouché's material may be an error (he has made the same error with "*Ap.*" *rosea*), and the "hearts" of x-xi could possibly be the extra-oesophageal vessels which have been mistaken for hearts by other researchers numerous times. Dorsal pores are quite variable in this species (see Fender, 1982).

Description (Gates, 1974a; pers. obs.)

Small worms, round in x-section, pale reddish with paler ventrum and "epaulets" on 9-11. Length 26-62 mm. Segments 125-137. Tubercula pubertatis 30-32, in mature specimens sometimes extending part way onto 29 and 33. Clitellum (28)29-33(34). Genital tumescences occur in the range of 22-26, as a band in the clitellar ventrum, and as glandularity in the "epaulets." Male pores in small prominent porophores in 15 which extend part way onto 16. Sper-

mathecal pores minute in *D*, 9/10 and 10/11. Dorsal pores extremely variable beginning in 17/18 or further back, or even lacking (5/6-7/8 according to Bouché). Nephropores alternate with great regularity between two levels in *B* and *D*, and asymmetrically on the two sides. Setae widely separate, not paired. Prostomium epilobic.

Septa all delicate. Calciferous sacs are lacking. Calciferous gland opens in xi, swollen in posterior xi and xii, constricted at 11/12. Typhlosole simply lamelliform, or with a slight groove midventrally. Ventral groove opposite the typhlosole lacking. Nephridia without glandular dorsal mesentery. Nephridial vesicle J-shaped, the ventral (hooked) end recurving anterodorsally into the body wall in *B*. Last hearts are in ix. Extra-oesophageal connections to the dorsal vessel in x and xi. Spermathecae two pair in ix and x at 9/10 and 10/11, stalked. Seminal vesicles three pair, anteseptal in ix, postseptal in xi and xii. Atrial glands visible internally, also glands associated with tubercula and genital tumescences. Testis sacs absent.

Genus *Dendrodrilus* Omodeo, 1956

Systematics

Like many other segregates of that wastebasket of small lumbricids, the classical genus *Dendrobaena*, this genus represents a taxon which cannot reasonably be placed with *Db. octaedra*. The U-shaped nephridial vesicles with the ental limb anterior, and the calciferous sacs opening vertically in posterior x, both point to relationship with *Lumbricus, Allolobophora*, or *Bimastos*, especially the latter. Differences in such features are setal spacing and the exact character of the calciferous sacs, as well as sexual characters, preclude placing the following species in that genus, however. Among the peregrine lumbricids, this genus is somewhat isolated and contains only two degraded parthenogentic morphs of a single species (see below).

Dendrodrilus rubidus (Savigny, 1826) f. *tenuis* (Eisen, 1874) [= *Bimastos tenuis, B. constrictus* (Rosa, 1884)]

Identification

Dendrodrilus rubidus f. *tenuis* has widely paired setae, epilobous prostomium, clitellum (25)26-31(32), irregularly alternating nephropores, reddish colour, with a noticeable sharp line between the coloured dorsum and non-coloured ventrum between segments 15-26, dorsal pores beginning in 5/6 or thereabouts.

Tubercula pubertatis may be absent or present on (28)29-30(31).

Internally, the nephridial vesicles are U-shaped, the typhlosole is a simple lamella or vaguely bifid, seminal vesicles are in xi and xii (see Systematics). Calciferous sacs are in x, opening vertically at the posterior margin of the segment. Spermathecae are generally absent, occasionally present.

Distribution

This species is generally distributed west of the Great Plains (see Figure 20).

Habitat

This species has been recorded in the western United States in high organic matter sites. The most abundant populations have been in moist rotting wood such as old logs partly embedded in saturated soil, but the McKey-Fender collection contains specimens collected from coniferous and deciduous forest litter, moss polsters and tree holes, two different greenhouses in potting mixes containing *Sphagnum* peat, the older portions of compost piles and in leaf piles, leaf mats (*Quercus garryana* and *Fraxinus latifolia*) under running water, fecal chambers in stick nests of *Neotoma fuscipes* (dusky-footed wood rat), and under stones and chunks of wood in moist places, including seashore occasionally reached by high tide. Most of these sites have been high in organic matter with a high lignin content, and which has already undergone considerable decomposition. This worm is an opportunist, taking advantage of very small concentrations of its preferred substrate, and is probably aided in this by its parthenogenetic mode of reproduction.

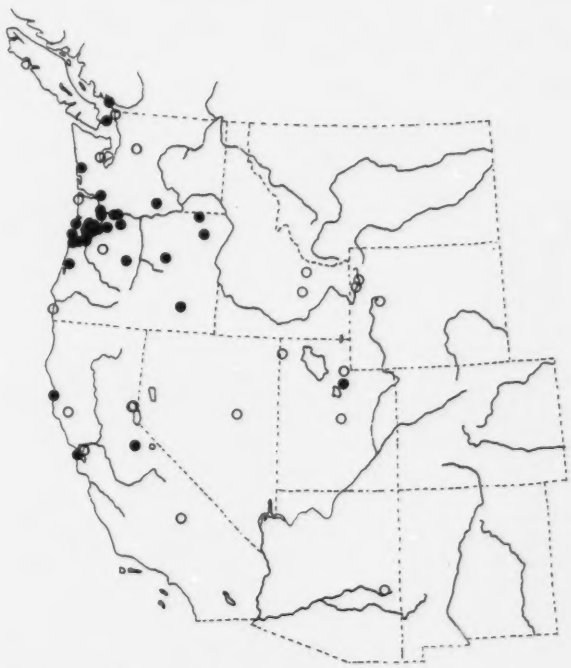

Figure 20. The known distribution of *Dendrodrilus rubidus* f. *tenuis* in the western United States.

This species is an active climber and, besides being found in trees, was once observed climbing the side of a house in San Francisco "by the thousands."

Gerard (1964) gives an almost identical list of habitats to the above, adding that *tenuis* was found in dung pats and in dunes and "machair" in the Hebrides (Boyd, 1956 *ex* Gerard, 1964). Graff (1953) says it is in the top soil layers of deciduous forest and in rotting stumps.

Systematics

Long thought to be a distinct species (*Bismastos tenuis* Eisen, 1878), this taxon is now considered to be a parthenogenetic morph of *Dendrodrilus rubidus* (Savigny, 1826). The other two forms of *Dd. rubidus, rubidus* and *subrubicundus*, are not found in the West. Though *Dd. r.* f. *subrubicundus* was reported once from California (Eisen, 1878 *ex* Gates, 1979), it is not in the McKey-Fender collection and all Gates (1979) localities are from the East. According to Smith (1977), "*Dendrobaena subrubicunda*" was collected from "wet soil more or less subject to sewage contamination" and habitats given by Gerard (1964) and Graff (1953) seem to corroborate that *Dd. r.* f. *subrubicundus* prefers a moister habitat and one with fresher, richer organic matter.

Dendrodrilus r. f. *subrubicundus* has three pair of seminal vesicles in ix, xi, and xii, and its spermathacae open in 9/10 and 10/11 in or above *C. Dendrodrilus r.* f. *tenuis* has only two pair of seminal vesicles in xi and xii and usually (not always) lacks spermathecae.

Description (Gates, 1979; pers. obs.)

Very small to small worms with a mostly rounded x-section and a flattened ventrum (creeping sole). Length 20 to 70 mm (mature specimens). Segments 90-105. Colour pale red on the anterior dorsum, elsewhere pale. Tubercula pubertatis usually lacking, when present (28)29-30, often on only one side. Clitellum usually 26-31, occasionally longer. Genital tumescences variable or lacking. Male pores on 15, porophores may form ventral pad reaching through 14-16. Spermathecal pores lacking. Dorsal pores usually begin 5/6. Nephropores alternate irregularly between two levels, above *B* and above *D*. Setae widely paired, not separate, *DD* much larger than *CD*. Prostomium epilobic.

Septa all delicate. Calciferous sacs very large in posterior x, opening in vertical slit at 10/11. Calciferous gland only moderately segmentally enlarged in xi, xii, and xiii. Gizzard obviously only in xvii. Typhlosole at first lamellar, becoming obesely bifid. A definite ventral groove flanked by ridges opposite the typhlosole. Nephridia without glandular lamella dorsally. Nephridial vesicle narrowly U-shaped, the limbs equal, the ental limb anteriad. Last hearts in xi. Extra-oesophageal vessel joins dorsal vessel in xii. Spermathecae usually lacking, occasionally present as one or more rudiments. Seminal vesicles two pair, postseptal in xi and xii. Atrial glands visible internally. Testis sacs absent.

Genus *Eisenia* Malm, 1877

Systematics

The accepted limits of this genus have varied tremendously over the years, and there is still no agreement on its members. *Eisenia foetida*, the generotype, is so peculiar that it is treated as a separate subfamily by Omodeo (1956 *ex* Gerard, 1964). The present treatment, however, follows Gates (1969b, 1978b). *Eisenia hortensis* and *zebra* are often described as *Dendrobaena veneta hortensis* and *Db. v. zebra*. Inclusion of these two species with *Db. octaedra* is unacceptable and they clearly have affinities with *E. foetida*. Similarly, inclusion of *Bimastos parvus* and *eiseni* in *Eisenia* (Bouché, 1972) is equally unacceptable even in the broad sense.

Included here in *Eisenia* are species with irregularly alternating nephropores; stout, rather sausage-shaped nephridial vesicles which open terminally; calciferous gland without calciferous sacs, the calciferous tubules opening in xi; and the last hearts in xi.

Eisenia andrei (Bouché, 1972)
(= *E. foetida unicolor* Andre, 1963)

Identification and Systematics

See *E. foetida*.

Distribution and Habitat

Similar to *E. foetida* (*q.v.*). Western records for this species are submerged in those of *E. foetida*, making it impossible to separate them at this time. A similar problem exists with literature references. The author's few observations suggest that *E. andrei* is usually found in the dryer parts of manure piles inhabited by *E. foetida* and is often most abundant in or below the soil contact.

Description

Like *E. foetida* but with pigment covering nearly the entire dorsum of each segment. (This author is as yet unable to distinguish these two species except by colour.)

Eisenia foetida (Savigny, 1826)

Identification

Both *E. foetida* and *E. andrei* have tubercula pubertatis covering segments 28-30, though often entering 27 and 31, as well as the bifid typhlosole, no calciferous sacs, calciferous gland opening in xi, "epaulets" bare of pigment in ix-xi, and stout sausage-shaped nephridial vesicles opening terminally. *E. foetida*, however, has pigment covering only the center 2/3 or so of the dorsal half of each segment, giving a strongly banded appearance. In *E. andrei*, the pigment covers at least nine-tenths of the length of each segment dorsally, giving a nearly solid colour.

Establishment of *E. andrei* as a distinct species was quite recent (Jaenike, 1982) and possible only through histochemical techniques. Implications for ecological research are, however, extreme considering the importance of both these species in economic and experimental pursuits. A randomly assorted batch of worms from an old manure pile was anaesthetized by this author with a dilute $MgSO_4$ solution recently and the *E. andrei* proved much more resistant to anesthetization, remaining active after all the *E. foetida* were completely anaesthetized. This is merely one indication that these species differ physiologically and not just in colour. André (1962) showed that these two forms produced sterile hybrid F_1 offspring. A practical means of distinguishing these taxa must await more detailed work.

Distribution

The localities given on the map for this species are those left after excluding bait shops and commercial worm farms. Though *Eisenia foetida* is often said to be everywhere in compost heaps and manure piles, this distribution is not reflected in published records and probably depends on moisture levels and source of inoculum. In our experience, *E. foetida* rarely goes "wild" and then usually only in the vicinity of human activity (see Figure 21).

Figure 21. The known distribution of *Eisenia foetida* in the western United States.

Habitat

My records for *E. foetida* are from under cattle droppings, in compost and leaf piles, in old manure piles, under logs in pasture, and in tree holes filled with wet rotten organic material which is mostly castings of this species and the sowbug, *Porcellio scaber*, and which are derived from the rotting wood. It is often found crawling over the surface during wet periods and can take advantage of small concentrations of organic matter which are rather isolated from each other. A specimen was recently observed by D. McKey-Fender to be crawling over snow in midwinter, air temperatures being slightly above freezing. Another specimen was recently found in perceptibly warm mud in the Olympic Hot Springs, Olympic National Park, Washington.

Literature records give essentially the same habitat for this species (Gerard, 1964; Reynolds, 1977; Bouché, 1972; Graff, 1953).

This species was probably originally an opportunist, using small concentrations of organic matter such as wind drifts of leaves, rotting wood, animal droppings, or rodent nests.

This species is the major one cultivated in temperate zone worm farms. Specimens of the "Red Wiggler" and the "Soilution Worm" have been identified as *E. foetida*, though it cannot be assumed that all worms sold under those names are this species. Many are probably *E. andrei* and other cultivated worms. Other species in cultivation include *Lumbricus rubellus*, *Eisenia zebra*, and *Eurilus eugeniae*, as well as others. Much has been made of the benefits of adding earthworms to soil, but if this is the species added, unusually large amounts of manure or compost must be continually added to the soil to keep them there. Otherwise, the only "fertilizing effect" will be from the nitrogen in the carcasses and even this will be slight because most individuals will emigrate to more favorable habitat. Far different results would be obtained by adding *Aporrectodea trapezoides*, *Lumbricus rubellus*, or *L. terrestris*, providing that these species were not already present.

Because of the ease with which this species can be cultured, it has proven to be an ideal experimental subject and has provided much of the information we know today concerning "the earthworm." Practically every test which can be applied to an earthworm has been applied to this one. This is in one way unfortunate, because *E. foetida* is an unusual species and any extrapolation of its tolerance to chemicals, behavior under stress and physiology to other taxa must be considered suspect. On the other hand, since so much work has been done on it, it provides a valuable check on experimental methods and their reproducibility, it being a simple matter to run *E. foetida* through any experimental procedure to see if the results are comparable to those of other researchers.

Description (Gates, 1978b; pers. obs.)

Small to medium-sized worms with a flat ventrum (creeping sole). Reddish, colour confined to transverse bands in dorsum of mid-segment. Length generally to *ca.* 100 mm. [Gates (1978b) reported specimens which even strongly contracted were as much as 115 mm.] Segments 65-120, frequent abnormalities. Tubercula pubertatis usually 28-30. Clitellum usually 26-32, subject to variation. Genital tumescence variable, but present through clitellar region and often anterior to male pores. Spermathecal pores minute near mid-dorsal line of 9/10 and 10/11. Dorsal pores begin 4/5. Nephropores alternate irregularly between two levels, above *B* and above *D*. Setae moderately closely paired, *DD* interval wide. Prostomium epilobic.

Septa not thickened anteriorly. Calciferous sacs absent. Calciferous gland opens in mid-xi, slightly enlarged in xii-xiii, especially xii. Typhlosole bifid. A ventral ciliated strip present opposite the typhlosole. Nephridial vesicles short, "frankfurter"-shaped, opening terminally. Last hearts in xi. Extra-oesophageal connects to dorsal vessel in x. Spermathecae nearly or quite sessile at 9/10 and 10/11, sometimes crossing the septa. Seminal vesicles four pair, anteseptal in ix and x, postseptal in xi and xii. Atrial or other parietal glands not visible. Testis sacs absent.

Eisenia hortensis (Michaelsen, 1890)
(= *Dendrobaena veneta* var. *hortensis*)

Identification

This species, like *E. foetida*, *E. zebra*, and *Ap. rosea*, has spermathecal pores near the mid-dorsal line. Unlike *Ap. rosea* and *E. foetida* and like *E. zebra*, it has tubercula pubertatis on 30-31. The latter, however, has four pair of seminal vesicles (as opposed to those in *hortensis* which are three pair in ix, xi, xii) and definite banding of the colour, as well as usually more segments. *Ap. rosea* also has four pair of seminal vesicles, and calciferous sacs in x, as well as very narrowly paired setae.

Other characteristics of *E. hortensis* are the moderately widely paired setae, lack of calciferous sacs, stout, short nephridial vesicles, lamellar typhlosole, epilobic prostomium, spermathecal pores in 9/10 and 10/11, near the mid-dorsal line. Dorsal pores beginning in 5/6, nephropores alternating irregularly, and lack of pale "epaulets" on ix-xi (reddish-violet in colour).

Distribution

Eisenia hortensis is known from only two sites in the West: McMinnville, Oregon, and San Francisco, California (see Figure 22). The present status of the second population is unknown; the first is extinct (see below).

Figure 22. The known distribution of *Eisenia hortensis* in the western United States.

Habitat

E. hortensis was collected repeatedly over a period of years at a 100-year-old farmhouse in McMinnville, Oregon. It was found in abundance in the nastiest habitats, most abundantly in a saturated mixture of soil, coffee grounds and putrid organic sludge repeatedly drenched by warm water from a broken kitchen sink drain. Other habitats were in an old manure pile and under wet cardboard on a back porch. In the 1970's the house was connected to a sewer line and the broken drain repaired. Since then, collections in all available habitats have failed to yield *E. hortensis*, even in compost, manure, and in soil wet by a cold water drain from a washing machine. Our conjecture is that a combination of fresh organic matter and warm temperatures are required for this species. The only other western locality is San Francisco, where it was collected by Eisen prior to 1900 (Michaelsen, 1900 *ex* Smith, 1917) and by H. B. Leech in 1951. The latter collection was in the Golden Gate Park arboretum, but in an unknown habitat.

Modern attitudes toward sanitation are removing habitats which once supported a diverse fauna. While it would be convenient to assume that these species are simply opportunists which have taken advantage of man-made habitats to expand their range, in fact many have probably evolved within these habitats during the last 5000 years or so and have no "natural" range. Now the sink drain habitat, for example, is being altered not only by better sanitation but by the use of new detergents, drain cleaners, and other household chemicals.

While perhaps none will mourn the passing of a worm which survives only in the foulest of environments, it behooves us to recognize this as a truly adapted species, as natural as any (better smelling) eagle or redwood.

Gates (1972a) lists several records including "plant beds of pH 8.1, 'fetter erde', 'hot beds,' " and "a toilet bowl," *etc.*, all of which would seem to confirm the warm, organic habitat, though it is difficult to assess if they are as foul as the Oregon sites. Smith (1924) collected "more than three hundred specimens . . . from the banks of a stream flowing through Urbana, Illinois." Perhaps this stream was the unfortunate recipient of sewer outfalls? Gerard (1964) gives the habitat of "pastures, gardens, and forests" for this species. We are unable to equate his records with our experience. Perhaps this species is ecologically more plastic in its home territory.

Description (Gates, 1972a, 1968b; pers. obs.)

Small worms, length to *ca.* 60 mm. Segments usually 95-105 but extremes are 42-130. Color reddish. Tubercula pubertatis 30-31, often on ridges which extend 29-32, continuous or divided at 30/31. Clitellum (27)28-32(33). Genital tumescence in clitellar region (*ab*) 29-33, also found anterior to the male pores in *ab* or *cd*. Male pores at dorsal margin of small round porophores confined to 15, without slit. Spermathecal pores minute, near mid-dorsal line in 9/10 and 10/11. Dorsal pores begin at 5/6. Nephropores alternate irregularly between two levels, in *B* and *D*. Setae definitely paired, but not narrowly, *AB* less than ½*BC*. Prostomium epilobic, open.

Septa all relatively delicate. Calciferous sacs lacking. Calciferous gland opens at 10/11, fusiform centered on xii. Typhlosole a simple, low lamella. Ventral groove opposite the typhlosole lacking. Nephridia without dorsal glandular mesentery. Nephridial vesicles stout, bent anterodorsad near lower end to form J- or L-shape, opening terminally. Last hearts in xi. (Extra-oesophageal joins dorsal vessel in xii?) Spermathecae two pair near mid-dorsal line at 9/10 and 10/11, on either side of septa. Seminal vesicles three pair, anteseptal in ix, postseptal in xi and xii. Atrial glands inconspicuous in xv. Testis sacs absent.

Eisenia zebra (Michaelsen, 1902)
(= *Dendrobaena veneta* var. *zebra*)

Identification

Mature specimens can be determined as strongly banded worms with tubercula pubertatis on 30-31, which are on ridges on 29-32. *Eisenia foetida*, which is also banded, has t.p.'s on 28-30. The latter should also be distinguishable by its more closely paired setae, lamellar typhlosole, and only three pair of seminal vesicles. *Aporrectodea rosea* has, like the above species, spermathecal pores near the mid-dorsal line, but has more narrowly paired setae, is unpigmented, and has U-shaped nephridial vesicles.

Juveniles should be recognizable by the combination of strong banding, widely paired setae (*BC* only slightly greater than *AB*), bifid typhlosole, sausage-shaped nephridial vesicles, and lack of calciferous sacs. Only the setal character will serve to separate this from *E. foetida*, but that species usually has less than 110 segments.

Distribution

The only western record is from San Francisco, where they were raised commercially by a Mr. S. Billeci. The present status of this population is unknown (see Figure 23).

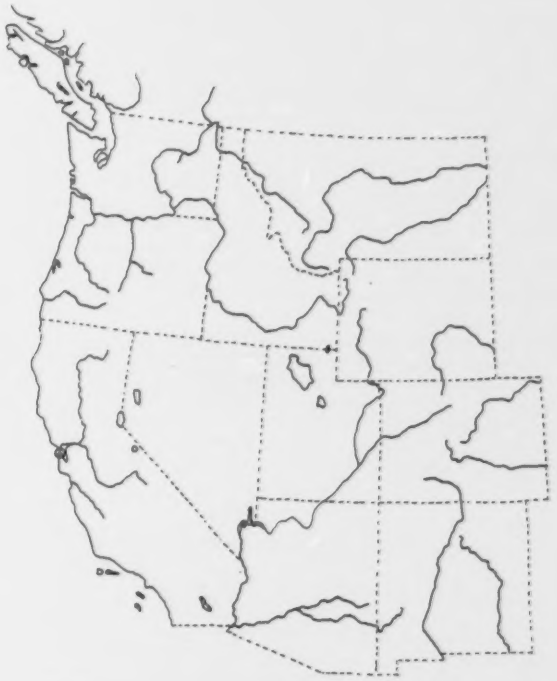

Figure 23. The known distribution of *Eisenia zebra* in the western United States.

Habitat

Gerard (1964) calls this worm "terrestrial" and gives only two English records. Gates (1969a) recorded the Billeci specimens, but without habitat notes. That it was cultured implies an organic feeder, possibly similar to *E. foetida*.

Description

Since I have no specimens of *zebra* in my collection, the following description has been of necessity taken from the literature (Gates, 1969a; Gerard, 1964).

Small to medium-sized worms. Length 50-120 mm. Segments 113-153. Colour restricted to segmental bands with wide unpigmented intersegmental bands. Tubercula pubertatis 30-31 on prominent ridges 29-32. Clitellum 26(27)-33. Genital tumescences in some or all of 9-12 and clitellar segments. Male pores on 15 on porophores limited to 15. Dorsal pores begin at 5/6. (Nephropores alternate irregularly between two levels, above *B* and above *D*?) Setae widely paired, *BC* slightly greater than *AB*, *DD* = 1/3 circumference. Prostomium epilobic, open, sometimes almost tanylobic.

Septa 5/6-12/13 strengthened, 13/14-15/16 muscular. Calciferous sacs lacking. (Calciferous gland opens in xi?) Calciferous gland fusiform, xi-xii. Typhlosole bifid ventrally, at first an inverted T, becoming less obvious. (Ventral groove?) Nephridial vesicle elongate sausage-shaped, opening terminally. Last hearts in xi. Extra-oesophageal joins dorsal vessel in xii. Spermathecae in ix and x, opening at 9/10 and 10/11 near the mid-dorsal line. Body wall bulged into coelom at location of atrial glands (xiv-xvi), genital tumescence glands project into coelom of ix-xii. Seminal vesicles four pair in ix, x, xi, and xii.

Genus *Eiseniella* Michaelsen, 1900

Systematics

This genus is of long standing as a separate entity and cannot be said to be close to any other recognized genus. Besides the peculiar position of the male pores which are usually in 13, *E. tetraedra* has a tetragonal x-section, a gizzard definitely confined to xvii, female pores median to *A* (contrary to lateral to *B* in most Lumbricidae), and possibly rudiments of a lateral line. That it is a lumbricid is testified by its other features: typical calciferous glands and sacs (though reduced), intestinal gizzard, lumbricid typhlosole, vesiculate nephridia, *etc.*, but it is a most peculiar one. The x-section may be related to the aquatic habitat, and the male pore position may be a result of parthenogenesis, but the remaining features probably are not.

Eiseniella tetraedra (Savigny, 1826)

Identification

This species can be recognized quickly and easily in most instances by the presence of deeply cleft male porophores on 13. No other western megadrile shows this characteristic. Occasionally the male pores are found on 15, and in that case preserved specimens can be recognized by their tetragonal cross section posteriorly, short sausage-shaped nephridial vesicles, green-brown colour, deeply cleft male pores, and anterior clitellum (anterior margin 20-23) with obvious tubercula pubertatis. In life, it can be recognized as the only species found in very wet habitats which has its peculiar green-brown to orange coloration and small size.

Distribution

Eiseniella tetraedra may be found anywhere in the western United States (see Figure 24).

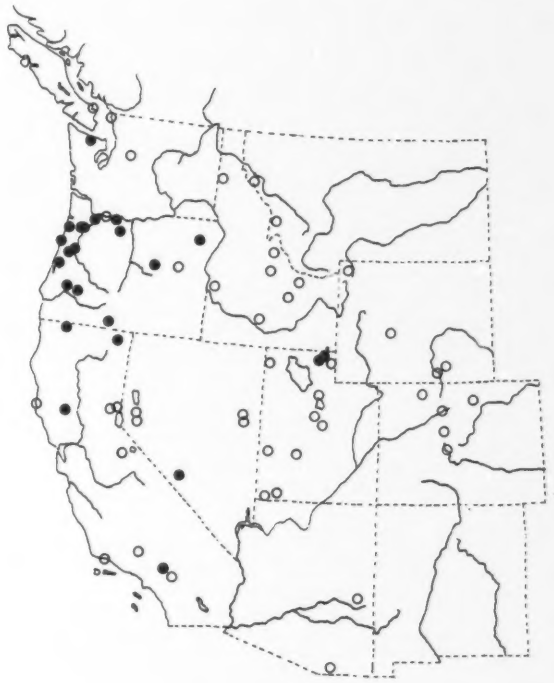

Figure 24. The known distribution of *Eiseniella tetraedra* in the western United States.

Habitat

Eiseniella tetraedra is one of the most generally distributed of earthworms. Its prime requirement is for large amounts of well aerated water and it is found in abundance especially in rocky streams and on gravel bars, where it is usually found under the larger stones in the saturated mud between the stones. *Eiseniella tetraedra* will ascend vertical seeps, either under moss or vegetation layers, or under the thin film of water. While it may be found in muddy streams amongst the roots of vegetation, mud is by no means necessary for it to thrive. Nearly all known sites for *El. tetraedra* are on stream or lake margins or in seeps, but an orange form of this species has been found in garden soil and compost piles in low-lying sections of Corvallis, Oregon, where the winter water table is very near the surface. The soil was saturated at the time. The following are selected Oregon habitats to illustrate the preference of this species:

Under pebbles and boulders in gravel bed of small stream in the Ochoco Mountains (alone).

In wet sand and root fibers between cobbles on a gravel bar of the South Umpqua River, south of Roseburg (with *Al. chlorotica* and *Eukerria saltensis*).

In clay and grass roots on margins of Dixon Creek, a small polluted stream in Corvallis (with *Db. octaedra* and *Al. chlorotica*).

Water-saturated clay loam among Jerusalem artichokes in a garden in Corvallis (February) [with *Al. chlorotica, L. castaneus, L. rubellus, Ap. turgida,* and *Geoplana mexicana* (a planarian)].

In organic muck of seep along Alsea River at Alsea Falls, Benton County (with *Sparganophilus* sp., *Ap. turgida, Kincaidiana hexatheca*) (the first and last are limicolous).

Gerard (1964:42) terms this species "amphibious" and lists almost exactly the same habitats as above. He also discusses three *formae* (*hercynia*, *macrura*, and *tetragonura*) which differ somewhat from the typical form. Of these, only *hercynia* has been reported from the West, differing from *typica* by possessing male pores on 15. This is a very rare form, probably an aberration rather than a true morph. Smith (1917) also notes this and two other *formae* (*neapolitana* and *ninnii*) from California. These differ from *typica* and *hercynia*, respectively, only by a more anterior clitellum, longer body, and more somites. Gates (1972a:109-110) lists reported habitats for *El. tetraedra* covering the same range as above.

Description (Gates, 1977; pers. obs.)

Small worms, ca. 30-60 mm long, greenish-brown, orange-brown, to golden-orange (rare), colour especially on anterior dorsum, quadrangular in x-section behind the clitellum. Segments 60-110, typically 80-90. Clitellum (22)23-26(27). Tubercula pubertatis usually ½23-½26. Genital tumescences anterior to male pores (in region of 8-10) and in clitellar region. Male pores in dorsal end of a broad cleft in a glandular tumescence confined to 13 (sometimes on other segments). Female pores median to *A* on 14. Spermathecal pores if present in 9/10 and 10/11, above *D*. Dorsal pores from 4/5, sometimes nonfunctional (?). Nephropores rather irregularly arrayed in *B* and *D*, often with long series in one or the other level, mostly in *B* in clitellum and male pore segments. Setae closely paired. Prostomium epilobic.

Calciferous sacs present in x, digitiform with a narrow opening in posterior x. Calciferous gland not enlarged in any segment. Typhlosole a simple lamella starting gradually at about xxi. No ventral groove opposite typholosole. Nephridial vesicle narrowly cylindrical curving anteriad and then down to parietes ectally in *B*. Last hearts in xi, extra-oesophageal vessel joins dorsal vessel in xii. Testis sacs absent. Seminal vesicles four pair anteseptal in ix and x, postseptal in xi, xii. Spermathecae two pair in x and xi or absent. Atrial gland prominent internally with deep obvious cleft in mid-xiii (usually). T.p. glands obvious.

Genus *Lumbricus* Linnaeus, 1758

Systematics

Members of this genus are easily distinguished from other western Lumbricidae by their tanylobic prostomium. This feature is shared only by *B. eiseni*. Other corroborative features are the definite tubercula pubertatis (absent in *B. eiseni*) which are located in all but the end two clitellar segments, the reddish-brown colour, narrowly paired setae, nephridial vesicles U-shaped with the ental limb anterior, and the digitiform calciferous sacs opening ventrally in posterior x.

This genus has four representatives in the Pacific Northwest. Three, *L. terrestris*, *rubellus*, and *castaneus*, are widespread, while the fourth, *L. festivus*, is so far known only by a single collection from southern British Columbia. While these species vary dramatically in size, behavior, and ecology, they are morphologically very homogeneous. Mature specimens can be distinguished easily by size and clitellum position, but juveniles are, somewhat unreliably, distinguished by their ranges of segment number. This, of course, does not help with posterior amputees. In life, *L. castaneus* is small, short, and a chestnut brown with strong green-violet iridescence. *L. terrestris* has many more segments and a flatter, broader tail and is a reddish brown to gray or greenish brown with less iridescence, while *L. rubellus* is intermediate in size, and variable in colour, but tending to a definite red. I have not seen living *L. festivus*.

Distribution

Of the three common species, *L. rubellus* is the most likely to be found away from human habitations and can be found deep into coniferous forest. *Lumbricus castaneus* has been found only in highly anthropic areas, typical collections being from under wet cardboard, on sidewalks, in piles of grass clippings, and in watered gardens. *Lumbricus terrestris* is intermediate in adaptability, being more usually found in lawns and gardens, but also extending into moist deciduous forest and agricultural areas.

Since this is such a homogenous group, separate descriptions of the internal features would be excessively repetitious. A generic description is therefore given below.

Description (personal observation)

Tanylobic. Setae closely paired. Colour some variant of reddish brown. Spermathecal pores two pair in *CD* vicinity in 9/10 and 10/11. Nephropores alternate irregularly among several levels, mostly slightly above *B* and well above *D*, starting with segment iii, first several pores above *D*. Body round in x-section and anteriorly, flattened (broadly trapezoidal) posteriorly.

Anterior septa slightly thickened. Anterior ventral longitudinal musculature very thick. Calciferous sacs in x directed anterodorsad, long, narrow, with small opening into oesophageal lumen, connected by small vessel to branch of extra-oesophageal vessel which joins dorsal vessel in x. Calciferous gland segmentally enlarged (moniliform) in xi-xii, (calciferous ?) tubules present in narrowed oesophagus in xiii-xiv. Typhlosole origin xxi-xxii, at first just transverse ridges which become elevated onto a longitudinal lamella in xxii-xxv. At maximum development, the typhlosole is a square-faced lamella with transverse ridges which are connected at the corners of the lamella, the ridges of each side being opposite each other and alternating with those of the ventral face, creating a vaguely "honeycomb" appearance. Ventral ciliated intestinal groove lacking. Nephridial vesicles in the form of an inverted J, the shorter (posterior) limb ental, the longer limb extending down to the level of *B* where it enters the parietes without first forming a definite duct. Anterior-most nephridial pair in segment iii. Posterior-most hearts in xi. Extra-oesophageal vessels join dorsal vessel in x (see calciferous sac above) and xii, the latter branch generally empty in preserved specimens. Atrial glands not visible internally. Testis sacs enclosing testes and funnels are present, delicate in some specimens (occasionally lacking?). Seminal vesicles anteseptal in ix, postseptal in xi and xii, those of xii extending to level of xiii-xv, usually by pressing against septa rather than by penetration. Spermathecae two pair in posterior ix and x in the level of *CD*.

Lumbricus castaneus (Savigny, 1826)

Identification

Lumbricus castaneus is distinguished from other *Lumbricus* spp. by the clitellum covering segments 28-33 (tubercula pubertatis on segments 29-32). This one-segment distinction from *L. rubellus* is of no aid for immature specimens. *Lumbricus castaneus*, however, is a chestnut brown anteriorily with very strong iridescence, while *L. rubellus* is usually distinctly redder, and *castaneus* generally has less than 95 segments, while *rubellus* usually has more than 100 (but cf. remarks under *rubellus*).

Distribution

Western records are almost all from the moister portions of the Pacific Northwest (see Figure 25).

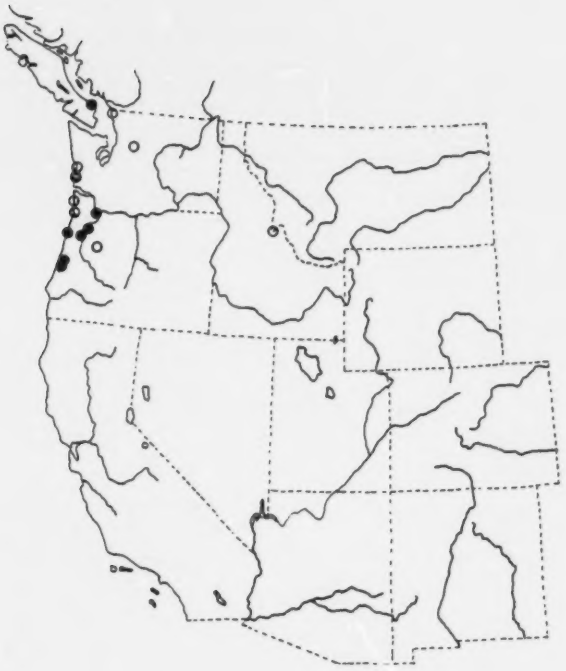

Figure 25. The known distribution of *Lumbricus castaneus* in the western United States.

Habitat

This species has been found in the Pacific Northwest only in areas very highly influenced by people. It seems to require relatively fresh organic matter, but does not live in masses of foetid decaying matter which are inhabited by *Eisenia foetida*, but instead has been found in fresh piles of grass clippings, under recently deposited boards on lawns, under cardboard boxes on sidewalks, under wet mops, in leaf piles, as well as in the top layers of garden soil and around the bases of plants. This is an active, irritable species which is an excellent climber. It has been found in drip pans, having fallen through a leaking ceiling! *L. castaneus* is common in Maine (Gates, 1972a), while *L. rubellus* is rare. As noted above, the reverse is true in the Pacific Northwest. Whether this is due to ecological differences is unknown (though probable), because *L. castaneus* is still spreading in Oregon, having within the last three years colonized an old (100+ years) homestead in McMinnville, Oregon, without any coincident change in land use.

Gerard (1964) gives the habitat as "terrestrial; mostly in soil rich in organic matter; in gardens, parks, pastures, forest, and on river and marsh banks; under stones, leaves, and animal droppings."

Gates (1972a) has never obtained this species and *L. rubellus* at the same site, but this author has never found *L. castaneus except* in company with *L. rubellus*.

Description

Reddish brown (chestnut), generally with a strong green-violet iridescence. Length 30-70 mm, usually less than 50 mm. Segment number usually about 80-95, extremes 72-100. Clitellum covering segments 28-33. Tubercula pubertatis on segments 29-32. Male pores on dorsal margin of a very slight glandular tumescence. Spermathecal pores in *C* lines in 9/10 and 10/11. Dorsal pores supposedly start at 6/7 but are actually quite variable (5/6-8/9 or even farther back) (Gates, 1978; Gerard, 1964, pers. obs.).

Remaining features agree exactly with the generic description.

Lumbricus festivus (Savigny, 1826)

Identification

This species is distinguished from other *Lumbricus* spp. by the clitellum covering segments 34-39 (tubercula pubertatis 35-38). It is unlikely that this species will be collected by ecologists in Oregon, but may be encountered in northern Washington and in British Columbia.

Distribution

This species has been found only once in the West, in the Fraser River Valley in British Columbia (Reynolds, 1977b) (see Figure 26).

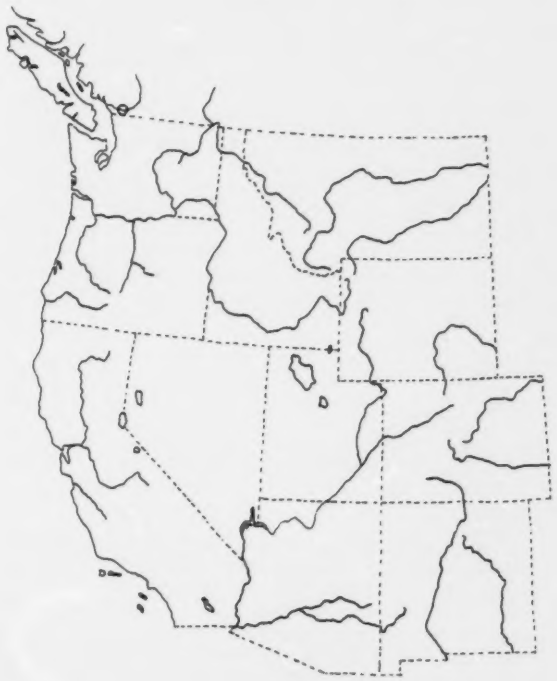

Figure 26. The known distribution of *Lumbricus festivus* in western North America.

Habitat

The habitat of *L. festivus* is essentially unknown. While Reynolds (1977) collected it under logs, debris, and leaves, Gerard (1964) states that it is found "In pastures, on river banks, in soil beneath dung, leaves, and under stones." Considering the rarity of the species and the abundance of such sites, neither characterization is of much help in deciding where to collect *festivus*. Graff's (1953) characterization "deciduous woods and evergreen [forest] land" (translated) merely adds to the confusion. It can be assumed from its northern distribution (entirely Canadian in North America) that

it requires relatively cold conditions to thrive, and from the statements of Reynolds and Gerard that it utilizes concentrations of organic matter rather than soil as food. Svendsen (1957 as reported in Edwards and Lofty, 1972) listed this species as one which will aggregate under dung pats.

Description

Ruddy brown, lighter ventrally. Length 48-110 mm. Segments 74-143. Clitellum covering segments (½33)34-39(40). Tubercula pubertatis wide, band-like on (34)35-38. Male pores in an obvious cleft of a large tumescence extending well onto xiv and xvi. Dorsal pores start at variable location (5/6?-15/16) (Gates, 1978; 1964; Reynolds, 1977a, 1977b).

Remaining features agree with those given for the genus (pers. obs.).

Lumbricus rubellus Hoffmeister, 1843

Identification

Lumbricus rubellus is distinguished from other *Lumbricus* spp. by the clitellum covering segments 27-32 (tubercula pubertatis on segments 28-31). This is only a one-segment difference from *L. castaneus* which, however, is a smaller, browner worm with fewer segments. *L. rubellus* usually has more than 100 segments, while *castaneus* usually has fewer than 95. The possibility of hybridization among *Lumbricus* spp. (Evans and Guild, 1947) produces some uncertainty, and we have found specimens with the *rubellus* clitellum and *castaneus* segment numbers. These are rare, however, and are of little or no importance ecologically.

Distribution

This species is widely distributed through the West, but is common only in the moister portions of the Pacific Northwest (see Figure 27).

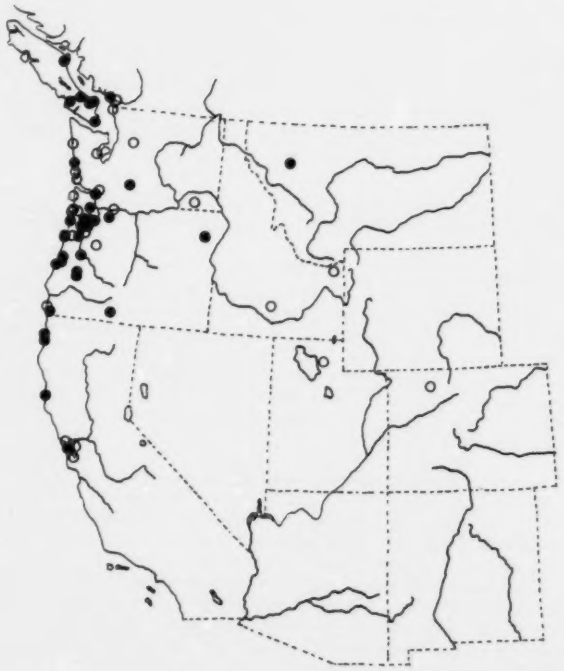

Figure 27. The known distribution of *Lumbricus rubellus* in the western United States.

Habitat

This is the most adaptable *Lumbricus* sp. It can be found in highly organic sites varying from gardens and old compost heaps to forest litter. Like all Lumbricidae, it is alien to the Pacific Northwest but has invaded natural areas, especially in the glaciated portions of Washington, sufficiently that Altman (1936) termed it "our most common endemic earthworm west of the Cascade Mountains." While *L. rubellus* has been collected away from water, in the Northwest it is generally associated with wet to moist sites such as garden soil, under tide water in an estuary (Salmon River, Oregon), in diked but still wet former salt marsh, under wood chunks in outflow from a peat bog, among roots of skunk cabbage (*Lysichitum americanum*), in recently deposited alluvial silt near the coast, *etc.*

Description

Red to reddish brown. Length 41-150 mm (usually 60-100). Segments 70-126 (usually 100-200). Clitellum covering segments 27-32. Tubercula pubertatis 28-31. Male pores in a vaguely defined glandular area of *BC* of 15, not a tumescence. Spermathecal pores two pair in *C* lines in 9/10 and 10/11. Dorsal pores start in region of 5/6-8/9 (usually 7/8?) (Gates, 1978a; Gerard, 1964; pers. obs.).

Remaining features agree exactly with the generic description.

Lumbricus terrestris Linnaeus, 1758
[= *Lumbricus herculeus* (Savigny, 1826)]

Identification

This species is easily distinguished from all other North American Lumbricidae by its large size (90-350 mm), reddish-brown colour, tanylobic prostomium, and clitellum covering segments 32-37. Immature specimens can be distinguished somewhat unreliably from other *Lumbricus* spp. by their greater number of segments (usually 140-155), the extreme range (110)160) overlapping slightly with *L. rubellus* and *L. festivus* (which see) on the lower end, and their size often being greater than that of mature specimens of the other species. All three common *Lumbricus* spp. may be found in the same site, especially in gardens, and in that case assignment of juveniles with intermediate segment numbers may be somewhat arbitrary, but where only *L. terrestris* adults are found, it can be safely assumed that juveniles are of that species. A little practice with living adults of the three common *Lumbricus* is a great aid to identifying the living juveniles, but is little, if any, help with preserved specimens.

Distribution

Lumbricus terrestris, despite being called "the earthworm" or even "the common earthworm," is relatively rare in the West, though it is locally abundant. It is likely to be encountered only in the immediate vicinity of human habitation or in other extremely disturbed areas. It is a poor traveler and has probably extended its distribution only with human help (see Figure 28).

Habitat

This is the species most people would call "the common earthworm," for the very good reason that, in cool temperate areas at least, it is abundant near dwellings and is often found on the surface where it feeds and copulates. Even in such areas, however, it is usually a poor second or third in abundance relative to various *Aporrectodea* spp. (see Introduction).

Lumbricus terrestris is found in moist, generally fine-textured, developed soils with a high influx of organic debris to the surface, thus it is found especially in lawns, gardens, and deciduous woods, being in very high numbers under unsprayed fruit trees, and thriv-

ing in irrigated areas. These worms make permanent burrows and feed on the surface, extending themselves out of ther burrows except for their tails which act as anchors. They feed on soft leaves, rotting vegetable debris, dead insects, animal droppings, and other organic materials. Small pieces of soft material will be swallowed *in situ*, while larger and firmer food stuff will be pulled back into the mouth of the borrow where, mixed with saliva, they soften and are eventually eaten. These worms can be a nuisance to flower gardeners by yanking valuable seedlings out of the ground and eating them. Their habit of pulling debris into their holes creates distinctive piles, rarely as much as 10 cm high, consisting of a mixture of leaves, soil particles, and other debris, mixed with tooth-paste-like castings, which cover the burrows in the daytime. No other species in Oregon is known to make these debris piles. Juveniles of *L. terrestris* are often found living in these debris piles in what may be termed a commensal relationship with the adults. Formation of these debris piles completely alters the habitat, destroying potential living space for litter organisms and mixing organic matter into the soil.

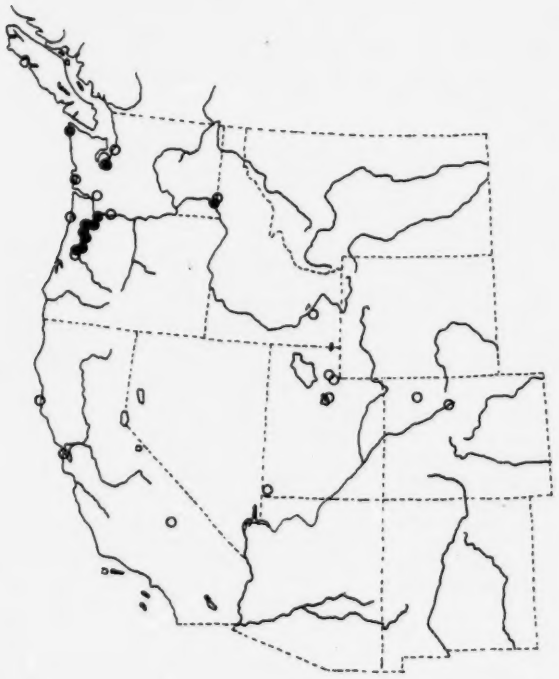

Figure 28. The known distribution of *Lumbricus terrestris* in the western United States.

From the time of Darwin's classical work "The Formation of Vegetable Mould Through the Action of Worms" (1881) to the present, the behavior and ecology of *L. terrestris* has been the subject of considerable scrutiny. Their behavior is complex, enough so that Darwin considered them to possess some intelligence. His main evidence for this was their ability to select the end of the leaf which could be pulled most easily into their burrows. A review of research on earthworm behavior, and on *L. terrestris* in particular, may be found in Edwards and Lofty (1972).

Lumbricus terrestris is tolerant of moderately acid conditions, but has not invaded coniferous forest, from which it is probably excluded by the unpalatable food supply which is high in polyphenols and C/N ratio. It thrives in maple (*Acer macrophyllum*) forest. It prefers fine-textured soils and has been introduced repeatedly into a lawn on a coarse sandy soil (Coos Bay, Oregon) without success.

Gerard (1964) says that this species is especially abundant in clay soils.

Reports that *L. terrestris* casts basically below the surface (Reynolds, 1977) are greeted by this author with a great deal of incredulity since this species and *Ap. turgida*, also said to be a non-surface-caster, are the dominant surface-casting species in much of the Willamette Valley of Oregon. Perhaps the reason for these reports is that *L. terrestris* mixes its castings with material dragged to the mouth of its burrows, somewhat disguising their nature. Gates (1972a) has also noted "appreciable surface casting at certain periods" and surface casting was noted for this species by Edwards and Lofty (1972), though not as much as was produced by *Ap. longa* and *Ap. nocturna*.

Description

Reddish brown dorsally, especially anteriorly, usually pale white, yellow-white, or pale reddish posteriorly but often entire body with a gray-green cast (or even almost black), giving the whole worm a "muddy" look. (These are considered a distinct type by local commercial worm collectors.) Length 90-350 mm. Segments 110-160 (usually 140-155). Clitellum covering segments 32-37. Tubercula pubertatis on part or all of 33-36. Male pores in lateral end of a moderate transverse cleft in a glandular tumescence confined to xv. Spermathecal pores in *C* or *D* lines, two pair of 9/10 and 10/11. Dorsal pores supposedly start at 7/8, but actually more variable (Gates, 1978a; Gerard, 1964; pers. obs.).

Remaining features agree exactly with the generic description.

Genus *Murchieona* Gates, 1978

Systematics

The peculiar calciferous sacs of this genus (see below) separate it dramatically from any known earthworm genus. Since it is monotypic, the characters of the genus are those of its single species.

Murchieona muldali (Omodeo, 1956)
(= *Allolobophora minima* Muldal, 1952, *A. muldali* Omodeo, 1956)

Identification

Like *Dendrobaena octaedra* and *Octolasion* spp., *Murchieona* has a single row of nephropores above *B*. Unlike them, however, its setae are closely paired and it lacks tubercula pubertatis. It is a small, pigmentless worm with an opaque clitellum from 27-33. Its most distinctive features are its calciferous sacs, which are without parallel in the other Lumbricidae known to this author. As described by Murchie (1956):

"A pair of well developed, finger-like esophageal pouches arises from the dorsolateral aspect of the gut in x. These project downward nearly the full depth of the esophagus . . . Frontal sections reveal each pouch to be formed of two chambers. The anteriormost of these . . . opens dorsally into the esophagus proper; the posterior chamber communicates dorsally with the intralamellar tunnels of the calciferous gland. These chambers join at the (distal) end of the pouch forming a continuous, U-shaped passage from the esophagus to the intralamellar tunnels. The calciferous gland itself extends from 10/11, without constriction, to 14/14."

Nephridial vesicles have not been described for this species, so it is not known if they are ocarina-shaped like those of *Db. octaedra* and *Octalasion*.

Bouché (1972) reported specimens of *Allolobophora (sensu lato) muldali* without calciferous sacs from France. This is either a misidentification, an erroneous description, or perhaps the species from Michigan is not the same as that originally described by Muldal (1952) from England and later renamed *muldali*.

Habitat

Though *M. muldali* has never been recorded from the western United States, it is included here because of its being the only known member of its genus, its having been reported from Michigan (Murchie, 1955; 1956; 1959), and Tennessee (Reynolds *et al.*, 1974). The fact that it is so small and specialized in its habitat as to be easily overlooked. It may very well turn up eventually (*cf. A. limicola*). Murchie's population was "restricted to a clay-loam soil near the base of a steep hill. The soil was wet, or at least moist, the year round, owing to seepage and to an extremely heavy cover of leaf litter . . . It was often possible to obtain thirty individuals from a single shovelful of soil. Despite its size, the entire population was confined to a narrow strip of soil scarcely more than 150 feet long and about 3 feet wide . . . [*M. muldali*] is to be looked for in the heavier soils, particularly those with a high degree of moisture stability." Muldal (1952) collected it in England "in rough pastures (river gravel), under rotten hay" and "in moist clay in forest ground, which had a thick cover of rotting grass interwoven with *Hedera helix* L." (English ivy). Distribution reported by Bouché (1972) is suspect, since his species supposedly lacks calciferous sacs (see above). Reynolds *et al.* (1974) reported one specimen each from "in a ditch and once in an old roadbed in a low wet area."

For a description of *M. muldali*, one should consult Murchie (1956).

Genus *Octolasion* Örley, 1885
(= *Octolasium*)

Systematics

The genus *Octolasion* in North America is represented by only two parthenogenetic species which, like the *Lumbricus* spp., differ mainly in features of size, clitellum, and tubercula pubertatis position and slightly in ecology. It has been suggested with some justification that they are merely two clones of a single species and that the one-segment difference in t.p. position and the larger size of *O. cyaneum* is simply due to its being more polyploid (Gerard, 1964). While these two species have European relatives, they are quite isolated in the American fauna. Only *Dendrobaena octaedra* and *Db. pygmaea* are known to share the peculiar ocarina-shaped nephridial vesicles, and only those species and *Murchieona* share a straight series of nephropores near line *B*. The above *Dendrobaena* spp. also share the widely paired setae, and are possibly closely related to *Octolasion*, though lack of calciferous sacs in *Db. octaedra* and the differing typhlosoles contraindicate a very close relationship.

Nomenclature

The name of this genus was changed to *Octolasium* by Michaelsen (1900), but by the presently accepted International Code of Zoological Nomenclature, this is an unjustified emendation and must not be used.

Identification

In the field, *Octolasion* spp. can be easily recognized as very pale unpigmented (rarely a muddy gray-brown) slimy worms with yellow tails (due to the coelomic contents of the last few segments) and a sharply demarcated saddle clitellum with linear, protuberant tubercula pubertatis along the margins.

Preserved specimens can be recognized by the widely spaced setae and obvious nephropores in a straight row just above *B*. In addition, they have ocarina-shaped nephridial vesicles (opening laterally), calciferous sacs in x, with the calciferous gland much enlarged in xi-xii, typhlosole bearing lateral flaps anteriorly, and epilobic prostomium.

The two species can be distinguished by the following:

Clitellum on 29-34, tubercula pubertatis on (½29)30-33(½34) ..... *O. cyaneum*

Clitellum on 30-35, tubercula pubertatis on (½30)31-34(½) ..... *O. tyrtaeum*

In addition to clitellar and t.p. characters, the species differ in size, up to *ca.* 160 mm for *tyrtaeum* as opposed to as much as 220 mm for *cyaneum*. Overlap is considerable, but in a series of mature *Octolasion* of variable sizes, the large ones are likely to be *cyaneum* and the small ones *tyrtaeum*.

Octolasion cyaneum (Savigny, 1826)

Identification

See under the genus.

Distribution

This species is rare in western Oregon, but replaces *O. tyrtaeum* as the most common *Octolasion* in northern California. It is rare outside the coastal belt (see Figure 29).

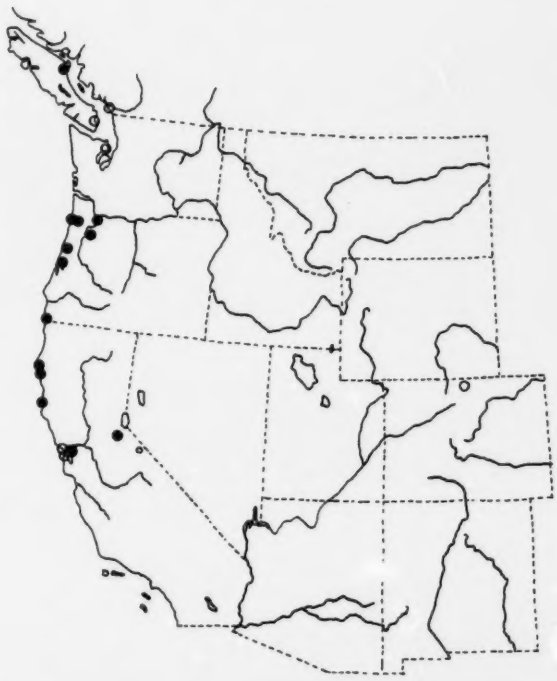

Figure 29. The known distribution of *Octolasion cyaneum* in the western United States.

Habitat

Octolasion cyaneum in the Pacific states is associated with woodland and is rarely, if ever, found in a true grassland situation. Most records are from flood plains, especially those with an annual deposition of silt, and with a cover of deciduous or other broadleaf trees or Cupressaceae (cedar or redwood). This is often the predominant species in grazed wood lots or pasture reverted to forest, and especially thrives under blackberry (*Rubus discolor*) thickets. Associated soils are often coarse-textured, silts, or sands, but not clays in our experience.

Gerard (1964) gives the habitat of this species as "Terrestrial; more abundant in argillo-calcareous and moist soil, occasionally in limnic habitats; mostly under stones, and occasionally under moss. Bouché (1972) says it is neutrophile and strongly acid-tolerant and lives in a slightly organic environment, and that it lives near the surface but in the soil. Satchell (1955 *ex* Edwards and Lofty, 1972) classifies *O. cyaneum* as ubiquitous with respect to pH.

Description (Gates, 1973; Gerard, 1964; pers. obs.)

Medium-sized to moderately large worms, round in x-section. Length to 110 mm contracted, to 220 mm extended. Segments 104-162. Unpigmented, any colour being due to blood, coelomic fluid, or gut contents, but with a definite yellow colour of the last few segments due to coelomic contents. Tubercula pubertatis band-like, protuberant, slightly shorter than the clitellum, of 30-33 but extending at maturity onto 29 and 34. Clitellum 29-34. Male pores in deep clefts on porophores on 15. Spermathecal pores between *C* and *D* in 9/10 and 10/11. Dorsal pores begin 9/10-13/14. Nephropores in a straight series in or slightly above *B*, except anterior to 15 somewhat above *D*. Setae separate behind clitellum, *AB* greater than *BC*, more narrowly paired anteriorly. Prostomium epilobic, open.

Septa 6/7-14/15 thickened. Calciferous sacs large, vertical in x. Calciferous gland enlarged in xi-xii. Typhlosole at first a vertical lamella flanked by four pair per segment of transverse flaps, posteriorly flaps fusing to form an inverted, reflexed T with a median ridge flanked by two longitudinal grooves and four pair per segment of transverse grooves which do not reach the edge of the T, the median ridge and transverse grooves eventually disappearing to form a smooth ventral face of the T, but with a single, median longitudinal groove. A definite ventral groove flanked by ridges lies opposite the typhlosole. Nephridial vesicles ocarina-shaped, opening laterally, very long. Last hearts in xi. Obvious large connection of the extra-oesophageal to dorsal vessel in xii. Spermathecae sessile in *CD* in ix and x at 9/10 and 10/11. Seminal vesicles four pair, anteseptal in ix and x, postseptal in xi and xii. Atrial glands bulging peritoneum in xv, but not coelomic. Tests sacs lacking (see below).

Testis sacs have not been observed in *O. cyaneum* or *O. tyrtaeum* by either this author or Dr. Gates (1973). What is meant by other authors who have reported such structures in this genus is unclear. Certainly these two species lack the well defined testis sacs characteristic of *Lumbricus terrestris*.

Octolasion tyrtaeum (Savigny, 1826)
[= *Octolasion lacteum* (Örley, 1881)]

Nomenclature

The usual name for this species in the European literature is *O. lacteum* (Örley, 1881). *Enterion tyrtaeum* Savigny, 1826 has priority, but its identity has been questioned. This author follows Gates (1972a) in using the older name but it should be recognized that the last word has not been said in this regard.

Identification

See under the genus.

Distribution

This species is extremely common in the Pacific Northwest but very rare elsewhere in the West (see Figure 30).

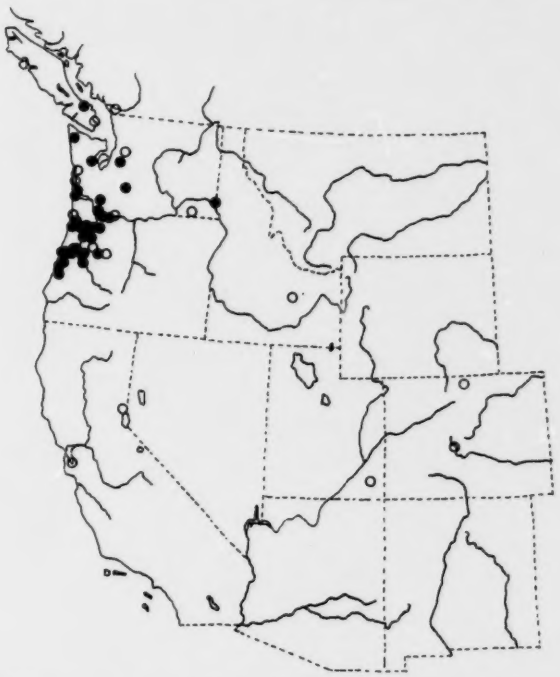

Figure 30. The known distribution of *Octolasion tyrtaeum* in the western United States.

Habitat

Records in the McKey-Fender collection are mostly from wooded habitats where it is an inhabitant of the lower litter (H) layers and the upper A_1. It is most frequent in moist areas near streams and in moist woods, being often found under red alder (*Alnus rubra*). It has been collected in peat bogs. Along with *Lumbricus rubellus*, it has penetrated farther into natural woodland than almost any other species, but requires some disturbance or flood plain conditions in order to do so. It is a characteristic species of seeps and is often found under chunks of wood or stones near water, whether or not a true soil is present. This species and *O. cyaneum* are very tolerant of coarse-textured soils. It is often extremely abundant in favored locations under alder, blackberry, or nettle, or combinations thereof.

Gerard (1964) says that "*O. lacteum*" is "widespread but never very abundant" in Britain and that it and *O. cyaneum* "seldom occur together" and that it is "terrestrial; more abundant in moist soil, occasionally in limnic habitats; also found under stones." Bouché (1972) says they are mountain-dwellers, neutrophile, and intolerant of acid (*cf. O. cyaneum*).

Note: *Octolasion* spp. which have been put into a closed container with a medium of different pH from that in which they were collected have been known to disappear without a trace in less than two days. It can be extremely difficult to work with this organism for this reason.

Description (Gates, 1973; Gerard, 1964; pers. obs.)

Small to medium-sized worms, round in x-section. Usually unpigmented, but some populations (northwest Washington) with a fairly dark gray-brown pigment similar to that of *Ap. trapezoides*. Length 25-118 mm, longer, to 160 mm if extended. Segments 100-137 (87-165 according to Gerard). Tubercula pubertatis band-like (½30)31-34(½35). Clitellum 30-35. Male pores in deep clefts on porophores on 15. Spermathecal pores in *CD* in 9/10 and 10/11. Dorsal pores start 9/10-13/14. Nephropores in a straight series just above *B*, except some anterior to the male pores above *D*. Setae separate *AB* = ca. *BC* behind the clitellum, more narrowly paired anteriorly. Prostomium epilobic.

Septa 7/8-14/15 thickened. Calciferous sacs definite, vertical in x. Calciferous gland enlarged in xi-xii. Typhlosole at first a vertical lamella bearing four pair per segment of lateral flaps which fuse posteriorly to form a T-shaped typhlosole bearing a median ridge flanked by longitudinal grooves. A definite ventral groove opposite the typhlosole. Nephridial vesicles ocarina-shaped (opening laterally). Last hearts in xi. Extra-oesophageal with very definite connection to dorsal vessel in xii. Spermathecae sessile in x and xi at 9/10 and 10/11 in *CD* (between setal lines). Seminal vesicles four pair, anteseptal in ix and x, postseptal in xi and xii. Atrial glands visible at least through the peritoneum in xv. Testis sacs absent (see note under *O. cyaneum*).

Genus *Satchellius* Gates, 1975

Systematics

Satchellius mammalis has long been known as *Dendrobaena mammale* but was described as a new genus by Gates because the combination of calciferous sacs opening posteriorly in x, sausage-shaped nephridial vesicles, conspicuous alternating nephropores, and red pigment was, according to him, not referable to any known genus. The presence of calciferous sacs and alternating nephropores clearly exclude this species from any genus containing *D. octaedra*. Whether *S. mammalis* actually might belong to a previously described European genus cannot be told at this time. Bouché (1972) listed this species as *Dendrobaena sensu stricto* and stated it to have nephropores in straight lines near *B* (but *cf. Db. attemsi*), and though he did also note calciferous sacs in x, he placed species with and without calciferous sacs in the same genus in more than one instance.

Satchellius mammalis (Savigny, 1826)
(= *Dendrobaena mammale*)

Identification

The combination of reddish pigment and tubercula pubertatis on 33-34 should be definitive in the West. Adding widely separate setae, sausage-shaped nephridial vesicles, and calciferous sacs in x should make an identification certain.

Distribution and Habitat

Satchellius mammalis, like *M. muldali*, has not been reported from the West but is included because of its distinctiveness and a single report of its presence in North America (Davies, 1954 *ex* Gates, 1975).

Gerard (1964) says this species lives in "the same type of habitat" as *D. octaedra* and that it is "mostly in soil of high organic content; under moss, stones, and old leaves; in pastures and marshy meadows, and near rivers."

For a description of *S. mammalis*, see Gates (1975).

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THE EARTHWORMS (ANNELIDA, OLIGOCHAETA) FROM THE PAMPA DE ACHALA (CORDOBA, ARGENTINA).

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RESUMEN

Entre Mayo 1983 y Julio 1984, se realizaron muestreos en la Pampa de Achala (Córdoba, Argentina) para determinar la presencia de lombrices de tierra. El estudio reveló la presencia de cinco especies representando cuatro géneros. Las lombrices se colectaron manualmente considerando la cobertura vegetal predominante, además bajo piedras y excrementos. Tres especies se agregan a la lista de lombrices de tierra de la Pampa de Achala: *Eisenia foetida, Octolasion cyaneum* y *O. tyrtaeum*.

ABSTRACT

Between May 1983 and July 1984, collecting was carried out in Pampa de Achala (Cordoba, Argentina) to determine which species of earthworms were present. This study determined that five species representing four genera were present. The earthworms were collected manually considering the vegetative cover as well as under rocks and excrement. Three species are added to the list of earthworms from Pampa de Achala: *Eisenia foetida, Octolasion cyaneum* and *O. tyrtaeum*.

INTRODUCTION

We know very little about the terrestrial oligochaete fauna of Pampa de Achala and that is only recent information. Mischis (1982) mentioned only two species from this region: *Microscolex dubius* (Fletcher, 1887) and *Aporrectodea trapezoides* (Dugès, 1828).

The object of this initial study was to make an inventory of this important soil fauna with the purpose of presenting a list of species that have a system according to an altitudinal habitat gradient as found in Pampa de Achala.

DESCRIPTION OF THE REGION

The study area is a high plain on a granite base located between 2000 and 2300 metres above sea level. It enlarges to about 60 km between 31°24' LS and 31°50' LS and reduces to 8 km between 64°45' LW and 64°52' LW. The climate is cold, windy and semi-humid with large daily fluctuations in temperature. In "El Cóndor" the mean annual temperature is 9.5°C, the absolute minima are very low and can go down to −15°C. The frost comes between March and November but it can also occur in other months. It snows in winter while heavy and irregular rains come in the spring and summer. Winds blow year round but more frequently in the spring (Capitanelli, 1979).

Phytogeographically, this region belongs to the high altitude grassland belt. The dominant vegetation is tall grass in the gorges (*Poa, Stipa* and *Festuca*) and some bushes (*Berberis, Baccharis* and *Cassia*); in protected places *Polylepis australis* woodlands ("tabaquillo, queñoa, a Rosaceae) where medium size trees mainly belong to the subtropical and tropical Andes.

In pure stands, or mixed with the above, appears the *Maytenus boaria* ("orcomolle"). There is also an important forage herb called sheep's forb or curly forb ("yerba de la oveja" or "pasto crespo", *Alchemilla pinnata*) a small Rosaceae that may form dense lawns accompanied by Cyperaceae, Juncaceae and Poaceae etc. (Luti *et al.*, 1979).

[1]Estudio realizado con ayuda del Consejo de Investigaciones Científicas y Tecnológicas de la Prov. de Córdoba (CONICOR).

METHODS

Between May 1983 and July 1984 collections were made in five places under pastures, groves, grass, dung and loose stones. The collection of earthworms was carried out by digging down to 30 cm and removing the soil manually. In areas where there was basal granite, stony soil, cow dung and loose stones, earthworms were picked up and observed. They were taken alive to the laboratory where they were narcotized by dropping them in 10% ethyl alcohol. For fixation, 10% formol was used. The identification was made using the classical literature.

MATERIAL EXAMINED AND RESULTS

All collections were made by the author and are deposited in his own collection.

ACANTHODRILIDAE

Microscolex Rosa, 1887

Microscolex dubius (Fletcher, 1887)

Under excrement and stones, 1 May 83; under excrement, 12 Oct 83; under excrement and stones, 8 Dec 83; under excrement and "mimbre" (*Salix viminalis*), 28 Jan 84; under excrement, 4 Apr 84.

Microscolex dubius is an introduced species probably coming from south of Patagonia, Tierra del Fuego and the south Atlantic islands. Being parthenogenetic, it includes male sterile morphs (Reynolds, 1974). It has been reported that *M. dubius* in one case was held between the pedipalps of a daddy-longlegs (*Sphaleropachylus fulvigranulatus* (Melo Leitao, 1930) possibly for feeding purposes (Acosta, 1983).

LUMBRICIDAE

Aporrectodea Örley, 1885

Aporrectodea trapezoides (Dugès, 1828)

Under forage herb, 8 Dec 83; under forage herb and "mimbre" (*Salix viminalis*), 28 Jan 84; under forage herb and excrement, 4 Apr 84.

This is another introduced species originating from Europe exhibiting parthenogenesis and male sterile morphs (Reynolds, 1974). *Ap. trapezoides* is one of the most common species in the different habitats.

Eisenia Malm, 1877

Eisenia foetida (Savigny, 1826)

Under excrement, 8 Dec 83; under excrement, 28 Jan 84; under excrement, 4 Apr 84.

This is an introduced species coming from Europe and commonly referred to as the "manure worm" (Reynolds, 1977). *E. foetida* is generally an amphimictic species with parthenogenesis in some morphs (Gavrilov, 1960). It was gathered in restricted numbers and in a limited habitat associated with other species.

Octolasion Örley, 1885
Octolasion cyaneum (Savigny, 1826)

Under "mimbre" (*Salix viminalis*), 28 Jan 84; under *Polylepis* woodland, 4 Apr 84.

This is another cosmopolitan European species exhibiting parthenogenesis (Reynolds, 1977). This species was the only one collected under the *Polylepis* woodland.

Octolasion tyrtaeum (Savigny, 1826)

Under "mimbre" (*Salix viminalis*) and grass, 28 Jan 84; under grass and excrement, 4 Apr 84.

This species is also and introduced European exotic earthworm which is obligatorily parthenogenetic with male sterility frequently present (Gates, 1973). This species was found in community association with many other earthworms.

CONCLUSIONS

The following species of earthworms have been recorded previously from Pampa de Achala (Mischis, 1982): *Microscolex dubius* (Acanthodrilidae) and *Aporrectodea trapezoides* (Lumbricidae).

The following lumbricid species are recorded for the first time from Pampa de Achala: *Eisenia foetida* (Savigny, 1826), *Octolasion cyaneum* (Savigny, 1826) and *Octolasion tyrtaeum* (Savigny, 1826).

This study examined 950 specimens collected from under excrement, stones, rocks, woodland, forage herbs and "mimbre". No earthworms were collected during the cold months (winter) or where the vegetative cover was composed of *Poa, Festuca* and *Stipa*.

All of the collected Lumbricidae are introduced European exotic species while *Microscolex dubius* (Acanthodrilidae) probably comes from south of Patagonia, Tierra del Fuego and the south Atlantic islands.

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CONTRIBUTION TO THE KNOWLEDGE OF SPANISH LUMBRICIDAE. V. *ALLOLOBOPHORA MORENOE* N.SP.

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INTRODUCTION

Little is known of the earthworm fauna of Galicia (NW Spain), which was first studied by Zicsi (1962). Alvarez (1971) included Galicia in the distribution range of certain species, and later Calvin and Rodriguez-Babio (1979) reported the presence of fifteen species, to which another twelve have since been added by Calvin *et al.* (in press).

During the current research program into the fauna and ecology of Galician earthworms, numerous specimens of a species differing from all these described in available references have been found. This species, which we have named *Allolobophora morenoe*, is described in the present paper.

MATERIAL AND METHODS

Specimens that have been dug up, found under stones, or driven out with 0.55% formalin, were fixed in alcohol-formalin and stored in 10% formalin.

In what follows, I, denotes immature specimens with no clitellum but not necessarily lacking papillae; SM, semi-mature specimens with papillae and incompletely developed clitellum, and M, specimens with completely developed clitellum (see *age classification formula* in Reynolds, 1977, p. 18).

Montefurado (Lugo; U.T.M. 29TPG49), holm and cork oak woods. 31-X-1982: 1SM, 5I. 15-I-1983: 15SM, 5I. 20-III-1983: 4M, 2I. 17-VI-1983: 1M, 3I. 12-XII-1983: 2M, 7SM, 5I. 21-XII-1983: 8SM, 2II.

Pontenova (Trives, Orense; U.T.M. 29TPH70), holm oak woods. 19-III-1983: 1M, 2SM, 6I.

Km 16 of the road from Sobradelo to Casayo (Orense; U.T.M. 29TPG79), holm oak woods with *Cistus ladaniferus* scrub.
16-I-1983: 1M, 2SM, 1I. 20-III-1983: 2M, 1I.

Telleiras (Viana do Bolo, Orense; U.T.M. 29TPG57), *Cytisus multiflorus* flora.
12-V-1983: 2M, 1SM, 6I.

All the above sites lie in the basin of the River Sil, a region with Mediterranean climate.

Five specimens have been deposited in the collection of A. Zicsi, and the remainder in that of the Zoology Department of the University of Santiago, where the holotype is identified as AM001.

DESCRIPTION

External: Live worms tanned flesh colour, rather darker dorsally, grayish after fixing; clitellum vivid brown in live worms and grey after fixing. Clitellate specimens 130-185 mm, 2.5-5.8 gr, though signs of clitellum may be present in smaller worms. The smallest immature captured were of 50 mm. Diameter 6-10 mm. Segments 155 (amputated?)—354.

Longitudinal furrows on proepilobous prostomium and segment 1, shallower on 2; segments 3 and 4 unfurrowed, one transverse furrow on 5-10, various shallow furrows on 11-16, three on 17-22 (the middle one deeper), one on each postclitellar segment. Relative inter-setae distances on 60: *aa*, 65; *ab*, 2; *bc*, 21; *cd*, 2; *dd*, 73. Setae *a* and *b* generally on large papillae on 11-16 and 29-40, except in the tubercular region.

First dorsal pore minute at (8/9), 9/110 or 10/11. Nephropores aligned 1/3-1/5 of the distance *bc* above *B*.

Male pores small slits with faint areolae on 15 between *b* and *c*. Female poreson 14 above *b*. Spermathecal pores absent. Clitellum horseshoe-shaped, from (22) 23 to (44) 45 (46), occasionally smaller in pre-adults. Tubercula pubertaria possibly shown by red patches, "in vivo", on (32) 33-35.

Internal: Septa thick and muscular, from (5/6) 6/7 to 9/10 (10/11). Hearts in 6-11. Nephridial vesicles bilobulate, slightly cucumiform when viewed dorsally, forming an open V when viewed laterally. Oesophagus without evaginations in 10, which lacks lamellae. Segments 11-13 swollen, with 30-45 lamellae on either side. Segment 14 narrow, lacking lamellae. Segment 15 practically reduced to a valve into the crop. In this region the septa are displaced by the seminal vesicles and the crop and the precise location of the various organs is not readily apparent. The crop seems to occupy 16-18 and the gizzard, which presents internal longitudinal striae, 19-21. Segment 22 small, resembling a folded valve. In 23-32 the digestive tract presents marked internal transverse folds. Typhlosole emerging gradually in 23 and 24, bifid at first, simple more caudally, caudal 25-35 segments atyphlosolate. Seminal vesicles in 9-12, small in 9-10, rather long in 11 and very large in 12, reaching to 18 or 19. Testicular sacs and funnels in 10 and 11. Deferents with no epidimia, which apparently joint in 12. Ovaries in 13, small ovisacs in 14. Spermathecae generally absent; only one of the twenty specimens dissected presented very small pairs of possible spermathecae in 9 and 10, which seem to show that these organs appear only vestigially in a small minority of individuals.

DISCUSSION

It is difficult to assign this species to any concrete genus. In Omodeo's (1956) classification it most resembles *Eophila* on account of its size, the number of segments and the clitellum. The lack of calciferous sacs in segment 10 might place it in Gates' *Helodrilus* or *Eisenoides* (Gates, 1978). Michaelsen's (1900) classification might place it in *Helodrilus (Allolobophora)*, Pop's (1948) in *Allolobophora*, and Vedovini's (1973) in *Eophila* or *Helodrilus*.

Bouché (1972) defined *Scherotheca* and *Nicodrilus* and subdivided *Allolobophora* in *Allolobophora s. strictu* and *Allolobophora s. lato*. In respect of its size, the number of segments and the position of the first dorsal pore, *A. morenoe* differs from *Allolobophora s.s.* and *Nicodrilus* and coincides with *Scherotheca*, from which it differs, however, in the absence of spermathecae (present in all species of *Scherotheca* except *S. dugesi dollfusi*), the presence of four pairs of seminal vesicles, the absence of oesophageal diverticula in 10 and the alignment of the nephropores in rows (though this arrangement is also found in some species of *Scherotheca*, e.g. *S. guipuzcoana*).

A. morenoe bears greatest resemblance to *Eophila* and *Scherotheca*, but since there are also differences, the species has provisionally been assigned to *Allolobophora*.

Apart from the general confusion among the lumbricid genera, with their ill-defined differentiae, *A. morenoe*'s position is further complicated by there being few similar species, the most being *Eophila dollfusi* Tétry, 1939, which supposedly also lacks spermathecae. Boulot and Gallissian (1961) redescribe the species with four pairs of both seminal vesicles and spermathecae, as does Védovini (1973). However, Bouché (1972), who named this species *Scherotheca dugesi dollfusi*, suggested that the original description may have been based on an immature or sexually regressive specimen. *A. morenoe*'s similarity is thus with Tétry's *E. dollfusi*, not with Boulot and Gallissian's or Védovini's. In any case, the two species differ in respect of tubercula, papillae and Morren's glands, and *A. morenoe* is also easily distinguished from *Eophila (=Scherotheca) dugesi* and from *Allolobophora (=Scherotheca gigas)*.

Derivatio nominis

This species is dedicated to Dr. Ana G. Moreno.

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SUMMARY

This paper describes a new species, *Allolobophora morenoe*, found in Galicia (NW Spain). Its inclusion in *Allolobophora* and its differences from other species such as *Eophila dollfusi* are discussed.

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